MENTAL MECHANISMS, CONTEXTUAL EFFECTS AND THE PROCESSING OF WORD-ATTRIBUTES

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ABSTRACT

It is known that the presence of information related to, but not necessary for the completion of a speeded experimental task can affect performance. Previous studies involving such 'contextual' effects with information in verbal and nonverbal form have produced mixed results which have been attributed to differing underlying processing mechanisms. The present work examines the extent to which some possible mechanisms could, in common, account for within- and cross-modality contextual effects. 'Priming' information relating to typographic case was presented over time intervals varying up to 480 msec before, and up to 480 msec after, a target to which a speeded category-decision was indicated by a left- or right-hand key-press. 'Within-attribute' case-priming was effected using a letter string printed either in upper- or lower-case (e.g., 'dghej', or 'YFLRB') paired with a similar target for case-decision. Within-attribute name-priming upon name-decision was similarly achieved using the case-denoting words 'upper' and 'lower'. 'Cross-attribute' priming was possible through name information priming case-decisions (e.g., 'upper-YFLRB'), or, case information priming name-decisions (e.g., 'YFLRB-upper'). The combined effects of case- and name-priming upon case-decision were also investigated using case-denoting words printed in either one or other of the two typographic cases (e.g., 'upper-yflrb', or 'UPPER-yflrb').

Relatively short decision latencies accompanied by relatively low error rates occurred when targets were preceded by congruent within-attribute primes. Incongruent priming led to slower responses with higher error rates. Similar effects were obtained with name-priming of case-decisions although, in comparison to within-attribute priming, these occurred after longer prime pre-exposures. Case-priming effects upon name-decisions were obtained for simultaneous as well as pre-exposed primes, however, congruent as well as incongruent case-priming led to relatively slow

decision latencies and higher error rates. Combined congruent case and name information speeded case-decisions in comparison to congruent case information alone. However the converse did not occur; increase in case-decision latency with incongruent case and name information combined was no greater than with incongruent case information alone.

It has been argued that the results are consistent with models which propose that input is initially subject to encoding where 'activation' may spread automatically among interconnected verbal or nonverbal representations. In particular, this could partly account for speeded responses obtained with congruent primes. Relatively shorter decision latencies can also be attributed to subsequent decision processes and the generation of responses. The results also suggest that relatively longer latencies could arise from competing incompatible responses having to be suppressed. It has been further argued that relative speed of processing different stimulus attributes and the form of experimental task can be major determinants in the detection of contextual effects.

CONTENTS

CHAPTER 1

INTRODUCTION AND HISTORICAL OVERVIEW

One of the concerns within psychology today is the nature of the mental processes which underlie our perceptions and actions, and the nature of the mechanisms which might support these processes. What lies within, however, may also depend upon what lies without. In general our environment provides a context within which we operate. That context may be described in terms of what is presently around us or in terms of past events. One way that we may attempt to discover the nature of what lies within is to manipulate what lies without and then make inferences on the basis of any effects that may be detected. This approach, of course, is by no means new and most of the activities of psychologists may be interpretable in terms of the study of contextual effects. It can thus be argued that the study of contextual effects is potentially very broad and before a focus is attempted some of the approaches that have been adopted in the past to the description and investigation of context and its effects will be briefly examined.

That the mind is an arena where past experiences may affect present and succeeding experiences is a notion that has been with us at least since the early Greek philosophers. For Aristotle the contents of the mind consisted essentially of images derived from previous sensations; mental organisation and functioning were considered to be largely determined by the order in which those images were presented. One way in which this was expressed was through a principle of 'association by contiguity'. This principle could, for example, be used to account for the way that one thought may arise from another and for the observation that items previously presented together were more likely to be recalled together. The associationist account of our mental experience also held an influential position in post-Renaissance philosophy with such figures as Hobbes, Locke, Hartley and Brown providing modifications. For example, Brown (c. 1820) expanded upon the theories available at the time through considering the observation that while on one occasion a bell may remind one, say, of a church service on another occasion it may remind one of a farmyard. In order to explain the strength, life-span and occurrence of such associations the concepts of frequency, recency and vividness were applied.

Although association had accounted for many common mental phenomena limitations in its explanatory potential were also evident. In the mid nineteenth century it was noted by Bain that although on some occasions experiences that had a degree of contiguity became associated there were also occasions when association was not apparent. It appeared that association was influenced by such factors as cause-effect, likeness and difference. However for such influences to occur it could be argued that some form of selectivity might operate prior to association. By the end of the nineteenth century, then, the explanation of present experiences in terms of past experiences had become complicated not only by virtue of a variety of factors concerning the history or form of their exposure but also because of the possibility of other mental activities that had yet to be explored.

Although an associationist account of the mind remained dominant within Western philosophy almost until the beginning of the twentieth century any developments were bounded by a single method of study that had been adopted. This method can also be traced back to Aristotle who believed that while thoughts could be the material of science they enjoyed a 'subjective' existence which was quite distinct from an 'objective' one. The mind was thus considered to be an entity which was only capable of being studied introspectively rather than through external observation. On this basis over the late nineteenth and early twentieth centuries psychologists in the Wundtian tradition developed methods of training subjects to systematically report their own mental experience. A major limitation of this introspective approach was opined by Galton (1883) who regarded the window on the mind afforded by the mental experience of which we were conscious to be but a small one in a vast array of automatic brain work. Galton, however, arrived at this conclusion through the use of introspective techniques; other experimental techniques which might have enabled him to explore new areas were not available.

A method that was to supersede introspection emerged initially as a result of what was essentially a contextual or priming effect arising within the course of physiological work. In 1902 Pavlov, while studying the salivary responses of dogs to food, noticed that if a dog saw a feeding bowl or heard the sound of the footsteps of an attendant who would normally deliver food then an increase in salivation would result regardless of whether food was presented or not. The finding from further investigations that salivation was predictable and even controllable from a variety of contextual events that were associated with the presentation of food led to the development of a science that was based upon behaviours that were observable. One of the early developers and popularizers of such a behaviourist approach was Watson who also demonstrated that the prediction and control of behaviour that was obtainable with animals was also obtainable with humans. As opposed to the data from introspections which were not generally available the data from the experimental studies that characterised behaviourism had an appeal because they were regarded as objective and available to all observers. The implications of behaviourism for contemporary psychology were profound: the notion of thought as a complex form of behaviour began to take root and psychology became defined as a science of behaviour rather than as a science of consciousness.

In spite of the radical change in method, then, the behaviourists were studying another facet of a contextual phenomenon which had occupied the associationists, namely, the effect of past events. Through behaviourism it was possible to find out what responses or memories might become associated as a result of the control of the spatial and temporal contiguity of external events. In the same way that only the conscious products of mental processing were considered by the introspectionists only the observable behaviours were considered by behaviourists.

A major question left unanswered both by introspectionists and behaviourists, however, concerns why contextual, or, associative effects might occur. If one is to attempt to consider the nature of the mechanisms that may underlie what we are conscious of or how we act then one has to look beyond the psychological work so far identified. An approach to psychology that was concerned with the description of underlying mechanisms emerged in Europe in the early part of this century as a result of attempts to study mental illness. The idea that mental activity could take place unconsciously was being developed by psychoanalysts who argued that much of human behaviour resulted from unconscious motives. The psychoanalytic theories which became established were concerned largely with how human feelings and emotion could be related to previous experience.

At about the same time as psychoanalytic theory was emerging there was a group of people in Germany who were concerned with the analysis of the conditions that gave rise to particular perceptions. This 'Gestalt' movement was concerned with the way that sensations were organized and made into patterns which could be recognized and manipulated. To this end a series of 'laws of context' or perceptual organization were formulated which drew attention to the more microscopic elements of our experience. The 'law of proximity', for example, described the grouping of items in terms of their spatial or temporal nearness while the 'law of good continuation' refers to the way we may predict ahead or simply to 'fill a gap' in an existing spatial or temporal array. Buhler (1908) emphasised the importance of a 'field' or activated knowledge base available to the perceiver; the relationship between field and prior events thus being a prominent one. In addition to looking at how different aspects of our experience may be related, Gestalt psychology was concerned with the active nature of the mind; this contrasted with the reactive portrait that was being offered by the behaviourists. Kohler (1925), for example, in his study of chimpanzees used the term 'insight' to imply that the animals were capable of organizing their perceptions of the environment so that problem-solving behaviour of an active and purposeful nature was possible. Although Gestalt psychologists managed to formulate laws such as those of perceptual organization their overall theoretical approach was not clearly defined and a precise scientific method of investigation was not developed within this context. This, coupled with the effects of Nazism in Germany, has led largely to the decline of Gestalt psychology.

The behaviourist and the psychoanalytic movement have continued to be influential, and further work relating to Gestalt principles has been carried out by those such as Gibson (1979). However more recently much of the activity of psychologists has been marked by the development of a so-called 'cognitive' approach. As with the earlier approaches the effects of context have a place within cognitive psychology. However before context in particular is focused upon the nature of cognitive psychology itself will first be introduced.

Although 'cognition' may simply refer to knowledge a central tenet in cognitive psychology is that the mind is an active agent, and the aim has been to try to establish what kind of mechanisms underlie our thoughts, perceptions and behaviours. One of the pioneers in this field was Neisser who in the 'sixties was using vocabulary and concepts that were not unfamiliar to the world of computing; these, for example, included 'information', 'processing', 'system', 'subroutine', 'input', and 'coding'. In particular it was also noted by Neisser (1976) that computers accept and classify input, manipulate symbols, recognise patterns, and store and retrieve items from a memory, and that these activities seemed to bear some resemblance to cognitive processes. Although it was not necessarily the belief that computers functioned internally in the same way as the mind the importance of the reference to computers was that they provided a concrete manifestation of some putative mental processes. Such concrete manifestations provided a focus strong enough to withstand extended study applicable to the psychological domain. An information-processing metaphor, then, provides the basis for a general theoretical framework within which cognitive psychologists hope to account for the activities of the mind.

In order to investigate internal mental mechanisms cognitive psychologists have adopted a scientific approach in the sense that the importance of testable theories and observable data is acknowledged. In this respect the mental events occurring within an individual while not being generally observable must be inferred indirectly from objective data. Since one form of objective data is observable behaviour cognitive psychology is at least in part a behavioural psychology in terms of its method although, of course, it remains distinct from behaviourism in terms of its content. In comparison to Gestalt psychology cognitive psychology addresses similar questions in terms of content but has the advantage of analytical tools, of which the notion of an information processing system is an example, and, experimental techniques which were not available to Gestalt psychologists.

At this stage it should, however, be remembered that the mind is a witness to what we do as well as to what we experience mentally. On this basis it may be argued that any method based solely on behaviour or on introspection will be an impoverished one. If one is to further develop an eclectic approach then it may also be argued that a study of the brain is relevant. This argument may be evidenced by the fact that many psychological texts contain information on the physical and chemical structure of the brain together with techniques correlating perceptions and behaviours with electrical activity, physical impairment or the presence of certain chemicals. That both physiological and phenomenological approaches have a place within cognitive psychology has been argued by Posner (1978) who considers the information processing metaphor as one which is capable of accommodating mental phenomena as the output of a specialized processing system while a consideration of the progress of information through different stages of a system is not out of keeping with physiological analyses.

The cognitive approach remains an active one with many variations on the information-processing metaphor being offered in conjunction with a variety of investigative techniques and the implications for the effects of context are many. In the next section some processing mechanisms and concepts that have been developed by cognitive psychologists are outlined. In view of the theme that has already been introduced some pointers regarding contextual effects in relation to the mechanisms outlined are also included. However it should be noted that at this stage the intention is only to introduce some possible mental structures and the main issues relating to them. On this basis a comprehensive justification of the mechanisms both in conceptual and empirical terms is not attempted; the empirical detail that is included is intended mainly to illustrate rather than justify the issues concerned. A more focused and rigorous discussion follows in Chapter 3.

MECHANISMS AND MODELS

Early Processing and the Notion of Levels

It is a fairly well-established neurophysiological notion that input to the perceptual system is processed at different levels. Within the visual sensory system dominant structural features exist such as the retina, the lateral geniculate nucleus (LGN) and the visual cortex. The visual cortex itself is arranged anatomically in layers represented by the location of successive synapses and the well-known findings by Hubel and Wiesel (1962), for example, suggest a certain hierarchy: at the layer where incoming fibres from the LGN terminate there exist 'simple' cells which respond to such basic visual features as edges and lines in particular parts of the visual field. At the next level there are 'complex' cells which respond maximally when more abstract conditions are met; position in the visual field for example becomes less important. 'Hypercomplex' cells at the next level respond with further conditions relating to such factors as line length or direction of motion. From this it has been argued that visual input is processed initially in small steps; each step using information provided by previous steps. However it should also be noted that further physiological studies in this area (see, for example, a review by Van Essen, 1979) suggest that the topography is a complex one which is characterised by many interconnections among visual areas which are not arranged in a straightforward way.

Hubel and Weisel's work is confined only to relatively basic neural mechanisms and it is tempting to extend the principle and postulate the existence of detectors of such complexity that they might respond only to a particular person or object. Konorski (1967) for example has developed this idea to include cells or 'gnostic units' which play a role in the recognition of relatively highly abstracted units of visual pattern. Hubel and Wiesel, however, used cell depolarization as an index and their work is essentially physiological.

Within the psychological domain similar ideas about processing stages abound. For example Craik and Lockhart (1972) have adopted the levels of processing concept. When applied to language relatively low levels of processing are said to correspond to simple graphemic or phonic features, these are then combined so that letters and word-names form intermediate stages while associations, categorizations and other semantic features form the substance of the higher levels. This approach also has implications for memory as it is assumed that information that is processed to a higher level, or more 'deeply', is also encoded more extensively and forgotten less easily. The work by Craik & Tulving (1975) lends empirical support to this view. Interpreted in an extreme form this approach also suggests that information-processing is serial in nature. As a result of input being processed through a series of stages our perceptions and our actions may be based on more abstract or semantic representations.

If elementary features or primitives are assumed to exist, then within the visual domain Hubel and Wiesel's work may lead to the suggestion that lines and angles are among the basic units of our perceptual processes. Many attempts at an analysis of the nature of the processing of words assume the existence of an initial stage where the contours of parts of a word or letter are considered as elementary distinctive features. It is assumed in this distinctive features approach (e.g., Massaro and Schmuller, 1975) that letters can be resolved into a set of graphemic entities upon which the categorization of input is based. Elementary features have not only been described in terms of lines and angles; among other suggestions is the idea that spatial frequencies may serve as a basis (e.g., Kinchla, 1977). The above theories have not been the subject of extensive exploration and the same is generally true of the early processing of letters and words. Henderson (1982) has pointed out that this may be due to a widespread tacit assumption regarding distinctive features along with a further assumption that the goal of initial processing is to identify each of the letters comprising a word-form. In this latter case it is thought that little would be lost when attempting to understand the later stages in word processing which in some ways are easier to investigate.

In general, then, the theoretical approaches that prevail either state explicitly or merely imply that incoming sensory data are processed first in terms of basic physical features from where they may be processed to varying degrees or levels of abstraction. In some ways it may appear logical to consider the course of processing as one beginning with input at a sensory receptor such as the eye. Here one may imagine sensory information providing the 'driving force' so that it is progressively built upon in a hierarchical fashion, gradually taking on some mental shape until a percept is arrived at. The terms 'bottom-up' or 'data-driven' have been commonly used with reference to this. A problem with this approach, however, may be illustrated by those pictures where a camouflaged or disguised object is not readily perceived unless a clue is given as to its identity. Thereafter the difficulty is generally not experienced upon subsequent presentation of the same pictures. Such an effect suggests the possibility that information already available at higher levels actively influences the outcome of processing initiated at lower-levels. The terms 'top-down' or 'conceptually driven' processing have thus been used; input is at least partly analysed in terms of what is expected, the expectations arising from existing stored high-level representations. The notion of top-down processing is of importance to the general idea, expressed by those such as Gregory (1980), that perceptions are hypotheses. With this in mind it may be regarded as essential that any mechanisms that are suggested allow for the provision of top-down processing.

If it is assumed for the moment that the starting point of the visual process is the detection of features then a question which arises concerns how featural information may be used to allow the recognition of larger units of information including whole object shapes. A number of models have been developed which suggest in some detail the mechanisms that might be responsible for the processing of input from the earlier stages. A 'template' model which relies on detectors which are finely tuned to respond to the shapes of particular objects may be one possibility, however there is an obvious problem regarding the number of detectors necessary to deal with the many possible variations of both object and viewpoint. In view of the problems regarding the plausibility of template models the recent focus has been on models which have a number of intermediate stages and methods of abstraction. Some of these are now briefly discussed. However since the immediate emphasis is on the different types of model detailed justifications have been avoided; any empirical details serve only to illustrate the nature of a model.

Pandemonium

An early model characterised by a series of processing stages that may underlie object recognition was the 'Pandemonium model' proposed by Selfridge (1959). The existence of detectors known as 'demons' was posited; they 'shout' when they detect a particular item. Demons are arranged hierarchically, the lowest-level 'image demons' record the arrival of an external signal. 'Feature demons' detect such basic features as certain types of line and angle while 'cognitive demons' are responsible for detecting more complex patterns; a letter for example. Demons listen to shouts from lower-levels and, according to how much information is relevant to their pattern of interest, they shout to the upper levels (hence 'pandemonium'). Eventually a 'decision demon' listening to the cognitive demons decides which is shouting the loudest and selects the corresponding pattern as the one most likely to correspond best to the input. This kind of model has been used to illustrate the process of letter recognition; cognitive demons being responsible for individual letter patterns. In principle, since a letter can be likened to any other object this model should also be applicable to the recognition of whole words and other types of object. The effects of context may also be included by the addition of contextual demons, however this is essentially an add-on feature to a model where the progress of recognition is determined by the activity of lower-level demons. The effects that may give rise to lower-level activity being influenced by such top-down factors as expectancy or perceptual set do not fall easily within its compass. Although the pandemonium model is an interesting metaphor it has not been rigorously developed in relation to empirical work.

Marr's model of Object Recognition

More recently, work carried out by Marr and his colleagues has received widespread attention. While Marr was initially concerned with the computations that may occur within neural structures this concern gave way to the overall functions that might be undertaken by such structures.

As a result of this he worked within the field of artificial intelligence and developed a model representing processes underlying object recognition.

Marr (1982) attempts to account in some detail for the processes linking a retinal image to the production of a semantic statement relating the image to specific knowledge of known objects. The retinal image or 'grey-level array' is analysed in terms of transitions in intensity, the result being a 'primal sketch' which is effectively a representation of image contours. The next stage of analysis attempts to sort out which of the contours represent the object outline and which contours represent the form of the object (or background) in terms of the orientation of surfaces in space. Up to this point no specific knowledge of particular objects is necessary; the resulting 'two-and-a-half-dimensional sketch' representing figure and ground is achieved through fundamental assumptions concerning the properties of matter such as that objects are relatively immutable and exist in one place at any one time and, appealing to various general perceptual processes, utilising depth cues such as motion parallax, stereopsis, perspective and shadow. At this stage only one view of the external scene is represented and this view may not link directly with existing knowledge which may have been modelled from other views of the world. In order for this link to take place the existing 'viewer-centred' analysis has to be generalised so that an 'object-centred' description, or model, is formed. This is achieved through deriving from the two-and-a-half-dimensional sketch a set of, what Marr calls, three-dimensional 'generalized cones'. The cones may be of varying size, with a major axis and may be linked. At this point the set of cones may be compared with a stored set of three-dimensional models representing the stored specific knowledge of the viewer. Comparison can take place at varying levels of detail implying a hierarchy in terms of description, for example a human being may register in terms of anything from 'upright object' to 'Aunt Mary'.

Since the work of Marr and his colleagues has been expressed principally as a computer model the extent to which it represents human mental functioning is, of course, open to question. Additionally, while Marr's work may have contributed to an understanding of what a visual analysis may be trying to achieve the model is one that is essentially driven by input. If it were not for Marr's untimely death it is possible that top-down mechanisms might have been incorporated more fully into the model; the paper by Marr and Nishihara (1978), for example, is suggestive of this.

Models Concerned Specifically with Word-Recognition

The prominent position enjoyed by verbal language within western culture has had implications for mental models. This is evident in so far that many cognitive psychologists have concerned themselves specifically with the processing of language. The recognition of words has in turn received much attention and models relating to this abound. Since such models are numerous a comprehensive coverage will not be attempted. Instead a summary of the main mechanisms and types of word-recognition model is provided. A general issue relevant to the analysis of the process of word-recognition is concerned with the existence of mediating perceptual units. Such units may, for example, include whole words, parts of words or letters. Any mediating units may also vary in form as well as in size as is evidenced in the interest that has been paid to the notion of phonological mediation as an alternative to visual access.

Letter Mediation

If, as with objects, one were to develop a model of word-recognition in terms of perceptual units of varying complexity it might seem natural to envisage processing of individual letters as a mediating factor. This is of course an issue, even if letter units did act as mediators this does not necessarily mean that the identification of individual letters is an independent operation that always precedes the recognition of a word-attribute such as name. One example that is often used to illustrate this point is the occurrence of 'A' in 'TAE' and 'CAT' (Selfridge, 1955). The fact that words composed of incomplete or half letters can still be read provides further support. Even if it is not argued that attributes such as word-names may be recognised independently of letter elements the effects of context still need to be understood. Letter identification, and also the recognition of many word-attributes, may depend upon interactions among various levels of processing, each level providing a context for the other.

It is also a possibility that within the representing world letters may not necessarily exist as physical letter forms but instead in terms of abstract graphemes. This has been suggested by McClelland (1976) who found that subjects' performance at reporting the typographic case of correctly identified words presented at threshold was poor. However these results require careful interpretation. Although McClelland required a report on case this attribute was not relevant to the experimental task. It is thus possible that the physical form of a letter might have been represented but not have been recoverable in those terms. Coltheart (1981) has suggested a model where units responsible for recognising the letter-form of an incoming stimulus output into an 'abstract letter identity unit' before a word-representation is activated. The existence of an abstract letter identity unit is supported by Evett and Humphreys (1981). Here it was found that when a word such as 'point' was briefly presented and followed by a mask consisting of randomly arranged letter fragments, so that subjects were not aware of its presence, then identification of the word 'POINT' similarly obscured, but to a lesser extent, was significantly more accurate than if it had been preceded by 'gravy' which is graphemically dissimilar. The word 'paint' and the nonword 'pairt', which have letters in common with 'POINT', similarly led to improved identification. An important aspect of the results in support of the notion of abstract letter units rather than mere similarities in graphical form was that the degree of improvement in performance was not significantly different if the effects of letters which are similar regardless of case such as 's' and 'S' were compared with the effects of letters such as 'a' and 'A' which have greater differences in visual form.

Should abstract letter identity units exist a further question arises regarding the nature of the information that is required for a string of letters to be recognised as a particular word. Categorizing input in terms of abstract letter units may be insufficient for word-recognition without further information relating to positions of letters within a string. It is here, perhaps, that a major difficulty arises when trying to formulate a mechanism that will cater for all the possible letter positions occurring within words ranging in length from one to a dozen or more letters. A further issue relevant to the mediation of abstract letter units within word-recognition concerns the role of word-shape. The overall 'outline' or 'envelope' of a word has been considered to be an important factor in the identification of words; with reference to this the difficulty of reading upper-case text has been compared to reading lower-case text. On this basis it has been argued that a model incorporating abstract letter identity units would have problems since word-shape information would soon be lost. However the importance of a physical feature such as word-shape upon word-recognition may be questioned by the findings from some experiments where normal word-shape was disrupted by the use of letters printed in alternating cases. Here it was found that both word-recognition (Besner, 1980) and reading aloud (Cohen and Freeman, 1979) were not significantly affected in comparison to normally printed words.

Phonological Mediation

Models which consider phonological coding to be necessarily involved in the recognition of printed words have been suggested by those such as Gough (1972), and Spoehr and Smith (1973). Generally such models are based upon rules governing the conversion of graphemes to phonemes. Among the difficulties that arise with such models is their inability to deal with homophones and irregular pronunciations. Evidence of such difficulties has also been found empirically; for example Baron (1973) found that phrases which were phonologically meaningful but visually meaningless (e.g., tie the not) were judged as meaningless just as quickly as strings of words which were both visually and phonologically meaningless (e.g., eat the walk). Models where phonological mediation is assumed to be both necessary and sufficient for word-recognition are generally not of current interest as it is now assumed that recognition and access to meaning can be carried out independently of phonological coding when words are presented visually. This of course does not deny that phonological recoding can have a role in the process of word-recognition.

Access to Lexical Entries

Given that the essential nature of the role of such mediating elements as letters, word-shape and sound is not easy to determine another approach to visual word-recognition that has been explored is one where whole words are considered as perceptual units. Within this approach the concern is how a particular item of input accesses a unique lexical entry, that is, one of a collection of many word-representations inside the head. Recently Carr and Pollatsek (1985) have attempted to categorise such models of word-recognition. Their groupings distinguish 'lexical instance models', where recognition depends directly upon a database of word examples, from 'parallel coding systems' models which are based upon the deployment of rules relating to various aspects of word structure.

Parallel Coding Systems Models

With Parallel coding systems models two mechanisms are basically at work; a lexicon which is directly visually addressable and rule-based phonological coding which may be deployed in the case of new or unfamiliar words. The progress of input through these different processing routes has led to the term 'horse race' being used. An issue within this group of models concerns the role of phonological recoding when familiar words are encountered. Of particular interest is how such models can deal with the possibility of conflicting output from the different mechanisms which may arise with familiar words which have an irregular pronunciation (e.g., done, two). One suggestion that has been offered far as conflict avoidance is concerned is simply to assume that the phonological system only attempts to deal with input that is unfamiliar to the visual system and vice-versa. This, however, requires some form of precognition or, at least, some method of pre-checking. If pre-checking is adopted then it may be argued that the recognition problem is subject to an infinite regression. The problem of conflict may be accommodated by assuming that the visual system operates more rapidly and conflict only occurs infrequently where input is either unfamiliar or in the face of certain unusual situations such as with experimental tasks in a laboratory (Coltheart, Davelaar, Jonasson, & Besner, 1977). In the case of conflict output from the phonological system has time to have an effect on further processing. A further possibility with parallel coding systems models is to assume that both direct visual access and phonological encoding occur regardless, and, that conflicts are somehow dealt with. However within this domain procedures for dealing with conflicts do not appear to have been articulated in any precise detail.

The discussion of parallel coding systems models has focused on conflict that may occur between visual access and phonological recoding. So far, however, little has been said about the mechanism of visual access itself. This will now be considered within the category of lexical instance models identified by Carr and Pollatsek (1985).

Lexical Instance Models

Rather than operating according to rules the main feature of lexical instance models is that direct visual access to a storage system representing 'instances' of individual words is necessary for word-recognition. Rule-like behaviour, however, may result from the use of exemplars or instances. Although 'instances' may refer to specific occurrences of inputs (e.g., Jacoby & Brooks, 1984; Whittlesea, 1983) and may be regarded as analogous to the templates discussed earlier, the term has a different meaning in the class of models identified by Carr and Pollatsek. In this latter context a 'lexical instance' may be equated with the notion of a 'prototype' as developed by Posner (1969). A prototype may be thought of as representing the mean of a number of variations; in this way the identity of 'lexical instances' is independent of variations in such properties as print size, ink colour or type face. Although the lexical instances comprising a mental database may refer to words the reference may also include letter clusters or subword units containing a meaning or 'morphemic' element.

Lexical instance models have been subcategorised by Carr and Pollatsek into 'logogen models', 'lexical search models' and 'verification models'. Each has a similar storage base but each has a different mechanism by which the representational elements within that base are accessed. These are now briefly described.

Logogen Models

The idea of the logogen was developed by Morton (1969) and is based on the assumption that direct auditory or visual access can be made to a mental storage system where individual words are represented. A logogen exists for each known word or morphemic unit; essentially it is an evidence collector for auditory or graphemic features. Each logogen is in direct communication with a 'sensory surface' to which incoming auditory or visual stimulus attributes are fed; if the input sufficiently matches the conditions specified for a particular logogen then that logogen reaches threshold and 'fires'. Since each logogen only represents prototypical properties for any given word the matching process rather than being dichotomous is one where evidence is built up. The processing of input is effectively carried out in parallel; the sensory surface is in contact with all logogens and a given input may result in 'evidence' for the existence of more than one lexical instance being built up. However as the process continues it is assumed that instances that have more in common with the input approach their firing thresholds faster that those with fewer similarities. Each logogen has an adjustable threshold, this is affected by such contextual factors as word frequency and recency of usage. Once a logogen fires it outputs to a 'cognitive system' which in turn feeds back to the logogen system. One function of the cognitive system is that it may provide a semantic context, that is, the feedback lowers the threshold of logogens of associate words. When a logogen fires the corresponding word is made available for output from the system. Without input the evidence-level of a logogen decays over a short period of time to zero.

Models which have similarities to that proposed by Morton have also been developed by Glushko (1979), and McClelland and Rumelhart (1981). In particular, McClelland and Rumelhart's work will used as a basis for further discussion.

Lexical search models and verification models

In contrast to logogen models which allow simultaneous or parallel access of input to all lexical entries, input with lexical search models is compared serially on an entry-by-entry basis. If a whole lexicon were to be searched in this way for each incoming stimulus the process would undoubtedly be very time consuming. Because of this, most search models that have been proposed incorporate some mechanism whereby the set of items to be searched is first reduced. The method of reduction for example might be by initial letter or sound, as is implied in Forster's (1976, 1979) search model. Input is first constructed in terms of a complete visual or auditory representation of a word (rather than individual features as with the logogen model). This representation is then compared with the contents of either an orthographic access file which contains visual representations of words or, with a phonological access file. Access files duplicate some of the information contained in a master file which is essentially a lexicon. Each access file is divided into 'bins' containing subsets of the total word population, each subset being delineated according to various auditory or visual qualities of words such as initial letter or sound and organized within each bin according to such factors as frequency of usage.

A further difference between logogen models and lexical search models is that while logogen models are concerned mainly with word units, lexical search models are based on morphemic representation. Another distinguishing feature is that lexical search models use a checking process; once one of the words on offer from the lexicon has been matched then the sensory input is accessed directly by the activated lexical representation as a final check or verification. This contrasts with the logogen model which depends on the output across a range of detectors effectively in competition. The precise mechanisms which allow for the possibility of final checking has in some models been seen as a major defining factor and as a result an identifiable subgroup of 'verification models' has been developed (e.g., Becker, 1976, 1979, 1980; Paap, Newsome, McDonald & Schvaneveldt, 1982).

Spreading-Activation

Many of the above processing models are based upon the existence of a large number of units representing elements of known information. This is applicable both with regard to letters or words as well as objects in general as already illustrated by Marr's model. Encoding mechanisms based upon such processing units have been further developed in the context of 'spreading-activation' models. Here the processing units are often referred to as 'nodes'. The nodes are interconnected and capable of assuming a level of excitement or 'activation'. Activation is assumed to spread from one node to another. The level of activation at a given node is also subject to decay (e.g. Anderson, 1983; Grossberg, 1980), this prevents an overall indefinite build-up which might otherwise arise as activation spreads. The notion of activation is consistent with a range of processes relating to stored representations of concepts and has been used to explain the rate at which processing information may proceed (Anderson, 1983), or, to explain the availability of information to decision processes (Collins & Loftus, 1975; Anderson, 1976).

The concept of spreading-activation may be seen as central in relation to contextual effects. This has been widely acknowledged (e.g., Anderson, 1976; Collins & Loftus, 1975; Meyer & Schvaneveldt, 1976; Posner & Snyder, 1975). For example the finite amount of time that activation is thought to persist has been used to explain the facilitation effect obtained when, after the presentation of a given input, a similar input subsequently presented within a short period of time is processed faster than dissimilar input. One notable study of this effect was carried out by Meyer and Schvaneveldt (1971) using word-pairs varying in semantic relatedness.

Although the range of spreading-activation models may be potentially varied most have been concerned with the representation of information at a semantic level only. On this basis contextual effects have been described in relation to differing semantic structures. One example of the way that our knowledge may be structured in terms of concepts has been considered by Quillian (1968). His 'semantic network' was developed as a model underlying human performance.

Semantic Networks

A semantic network consists of a collection of 'nodes' or locations containing information representing individual concepts. Nodes may correspond to words in a natural language but this is not a requirement. The nodes may be related by virtue of some form of association among the concepts they represent. The relations within the network determine its overall structure. With regard to this Collins and Quillian (1969) have suggested a hierarchical arrangement where, for example, properties specific to birds are stored with birds while those relating more generally to animals are stored with animals. In what is now a well-known experiment they found that a statement such as 'A canary eats food' took longer to be classified as true than the classification for 'A canary has feathers'. Collins and Quillian saw the essential difference between the two statements in terms of such phrases as 'eats food' being superordinate to such phrases as 'has feathers' in terms of a presumed hierarchy regarding animal properties. However although the 'eats food/ has feathers' contrast may suggest a hierarchy with regard to 'bird' and 'canary' it is easy to foresee problems when using other descriptive attributes to resolve objects which may be considered to be at the same level. For example even if low-level descriptive terms may suffice in the differentiation between, say, a shark and a herring it as also tempting to consider the possibility that higher-level concepts such as 'is dangerous' may enter into the comparison, and in some instances this may be necessarily implicated.

The above strictly hierarchical arrangement has been frequently questioned. For example Rips, Shoben and Smith (1973) found that 'A penguin is a bird' took longer to classify than 'A robin is a bird'. This suggests that mental organization exists in terms of prototypicality as well as, if not rather than, hierarchy. There is also the possibility that such findings are simply representative of the degree of association between words (Wilkins, 1971). A revised account of the semantic organisation proposed by Collins and Quillian (1969) has been suggested by Collins and Loftus (1975). Their model was organised in terms of semantic-relatedness rather than hierarchy. Semantic-relatedness is indicated by the links between concepts. Input that relates to a given concept results in the corresponding node being activated. Activation also spreads to other concepts that are linked and stronger links between associated concepts may result. Although the Collins and Loftus (1975) model overcomes some of the shortcomings of its precursors another approach to the organisation of concepts has also for some time been developed in various forms; this has been referred to as 'schema theory'.

Schema Theory

In his 'Critique of Pure Reason', Kant (1787) used the word 'schema' in relation to the way we actively organize experience. Bartlett (1932) has also used the term with reference to a central cognitive structure that is involved in our perceptual processes. More recently schema theorists have attempted to provide precise elaborations on the basic idea, often for the purpose of the development of computerised representations of knowledge. Rumelhart and Ortony (1977), for example, postulate the existence of a set of interacting knowledge structures which they call 'schemata'. Concepts are represented prototypically within this framework and a schema is thought of as a particular instance which is represented by a network of interrelations specific to it. As in the case of nodal structures, schemata can become activated so that contextual effects, or processing in terms of a particular attribute or category may result. One schema can embed within another and although this suggests a hierarchy, the nature of that hierarchy may be considered to be more general than that suggested, for example, by Collins and Quillian (1969) which is seen simply to be an order of inclusions. The generality results from the principle that one schema may make reference to a subset from a range of other schemata according to context and purpose. In this sense a schema may effectively consist of information relating to a variety of levels of abstraction. In spite of this, various workers have tended to concentrate within relatively narrow ranges. For example the representation of plots or stories has been studied by Charniak (1972), and Schank and Abelson (1975) while the representation of words has been examined by Anderson and Bower (1973), and Kintsch (1972) among others.

It may be argued that the degree down to which the abstraction of various levels of schemata are assumed to range inevitably reaches a point where some schemata have no subschemata from which to refer. Norman, Rumelhart, and LNR (1975) refer to the lowest-level units as 'primitives' which represent components of experience which can be subjected to no further analyses. Besides including elementary sensory features these components may also include basic sensory-motor procedures and 'causal-connection' (Rumelhart & Ortony, 1977),

The above models relating to spreading-activation have primarily been concerned with semantic structures rather than with the nature of processing leading to semantic representation. This latter concern is to some extent addressed by a group of recent models that have been referred to under the term 'parallel distributed processing' (PDP). Although these models are typically nodal and involve the spread of activation they may be contrasted with the earlier spreading-activation models. Rather than the emphasis being on semantic structure, the focus is broader so that processing at a variety of levels of representation may be considered. A further characteristic of PDP models is that they may contain inhibitory as well as facilitatory mechanisms; this differs from those earlier spreading-activation models where contextual effects have been described only in facilitatory terms. Since the ideas relevant to parallel distributed processing are pervasive with regard to encoding in general and also are becoming of widespread interest they will now be introduced in some detail.

Parallel Distributed Processing

Models grouped collectively as parallel distributed processing models (e.g., Rumelhart, McClelland & the PDP Research Group, 1986), while exhibiting different forms, are generally based on a set of processing units which are subject to varying states of activation. In some models such as McClelland and Rumelhart's (1985) distributed model of memory the units may represent abstract elements or feature-like entities and any concept or meaningful representation exists as a pattern of connectivity among the units. The 'connectionistic' approach has also been developed by Seidenberg and McClelland (1989). Here word representation is characterised by the activation of a group of distributed features rather than by word nodes *per se*. In some connectionist or distributed feature models there may be a close analogy between the units and neural elements or collections of neural elements (e.g., Anderson, Silverstein, Ritz & Jones, 1977; Grossberg, 1981). By way of contrast in another group of PDP models the units represent concepts as nodes in a network. The concepts may range from features and letters through to words and other larger meaningful entities. In both types of model the idea is that a large network of simple operations exists where each unit receives input from a number of other units from which it generates an output which is in turn fed back or communicated to a number of other units. Concurrent activity involving many simple processing elements underlies complex mental phenomena; there is no overall controlling or executive system. Such a situation may be perceived as essentially passive: to some extent this is acknowledged, for example solutions of problems may be settled into rather than calculated (Rumelhart & McClelland, 1986). However it is also argued that goals, or intentions, may themselves be considered to be stored patterns of activation. (Rumelhart, Smolensky, McClelland & Hinton, 1986). This issue concerning volition, however, appears to require further development.

The concept of activation is central to all PDP models and the levels of activation allowed for a unit vary from one model to another; levels may be both discrete and continuous, they may vary both positively and negatively and may also include a zero-level. The level of activation may also be subject to 'addition' rules so that the state of activity for each unit over the system may be determined. Most important to the nature of the system is the pattern of connectivity among the units. This pattern determines what each unit represents and additionally determines what can be stored within the system as well as how it will respond to input. Whether or not the system behaves in a hierarchical, top-down or bottom-up fashion is also a function of the pattern of connectivity. In general, then, PDP models may assume a number of forms. Two examples which are both relevant to the processing of words as well as being representative of the class of models where the units represent concepts in other forms are now given.

The Interactive Activation Model

The 'Interactive Activation Model' was developed by McClelland and Rumelhart (1981) in order to explain a range of empirical observations on word perception and also to relate in detail to the results of computer simulations. Figure 1.1 provides a simplified overall description. The

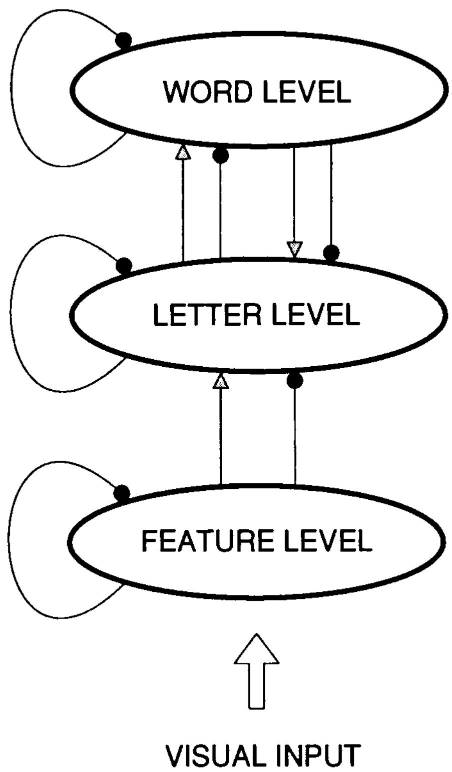


FIGURE 1.1 A simplified overall representation of McClelland and Rumelhart's (1981) interactive activation model of word-recognition. Excitatory connections are represented by lines ending with arrows and inhibitory connections by lines ending with circles.

model consists of 'detectors' or 'nodes' grouped into levels. Each level is responsible for the recognition of such entities as elementary visual features of letters, letters and words. There are nodes representing each item that is known to the system. At one level, for example, a node may exist for a particular letter of the alphabet in a particular position within a word while at another level a node may exist for a particular word. The existence of word nodes may allow this model to be classified as a logogen model. Each node is connected to a limited number of other nodes or 'neighbours' which may be within the same level and also in adjacent levels. The connections can carry excitatory or inhibitory signals. Excitatory signals increase the level of activation of recipient nodes while inhibitory signals decrease the level. A tonic level for a node in a quiescent state lies between the fully inhibited state and the fully excited state. A given node remains active only momentarily as activation is subject to a decaying process. Excitatory and inhibitory signals are transmitted to neighbouring nodes. The resultant activation of any one node is determined by the combined input from its neighbours. Connections within the same level are inhibitory as here the nodes are effectively competing so that a resultant single interpretation of any input to that unit is produced. Connections to adjacent units can either activate or inhibit nodes within those units. Input is initially processed at feature-level and excitatory and inhibitory connections may then be made to the letter recognition unit. Similarly excitatory and inhibitory links are made between the letter recognition unit and the word-recognition unit. However as far as these latter two units are concerned inhibitory and excitatory connections can be made in either direction, that is, information at word-level will in turn influence processing at letter-level. In this way processing is both top-down and bottom-up; this is significant in relation to the term 'interactive' being applicable to the model. Some details of the process of the recognition of a word may be understood through the example given in Figure 1.2. Here the letter 'H' occurring within the context of the word 'HAT' raises the level of activation of nodes representing letters which are consistent at a featural level and inhibits those that are inconsistent. Nodes representing words beginning with 'H' are then activated and in turn activation is fed back to consistent letter nodes. Words not beginning with 'H' are inconsistent and activation is inhibited. Similarly the remaining letters and word are recognised rapidly through both positive and negative feedback. Processing is continuous in the sense that no one stage of processing needs to be completed before another one can begin.

The Interactive Activation model has been used to account for the recognition of words in human memory. Another feature of human

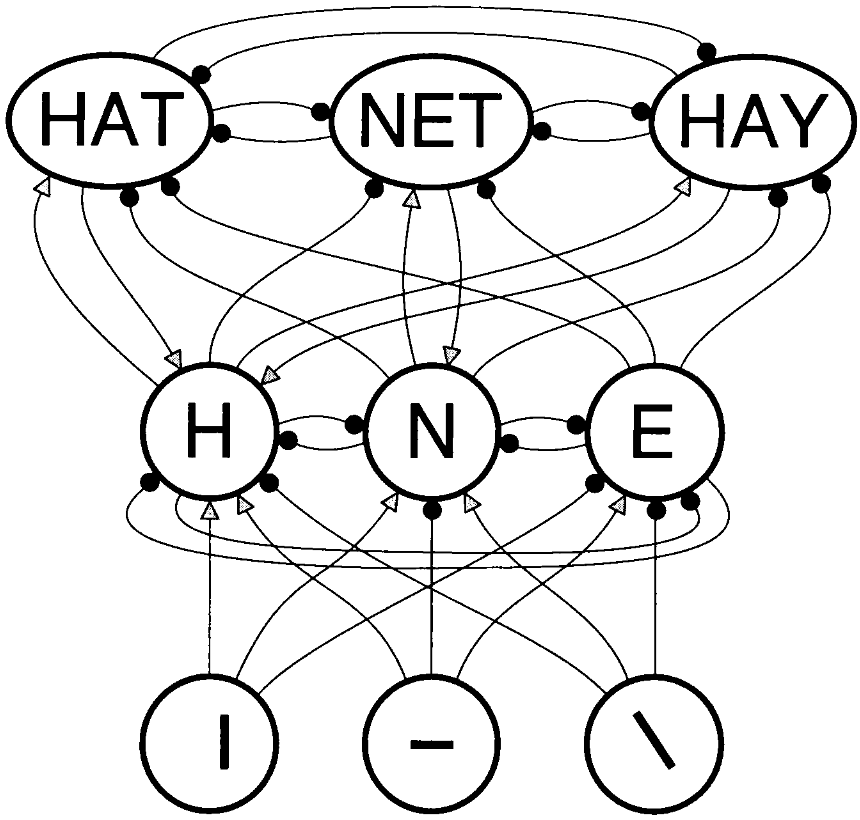


FIGURE 1.2 An example showing how excitatory and inhibitory connections may be involved in the course of word-recognition in McClelland and Rumelhart's (1981) interactive activation model. Excitatory connections are represented by lines ending with arrows and inhibitory connections by lines ending with circles. (Adapted from Rumelhart & McClelland, 1981.)

memory is that it is possible to recall a word on the basis of one or more of the variety of its attributes. A number of PDP models have been developed to account for this phenomenon and one developed by McClelland (1981) may be used to illustrate the main underlying principles.

McClelland's Model

McClelland's (1981) model consists of a network where 'instance units', each representing a particular object in memory, are linked to elements within groupings of units representing the properties of objects. The links allow the units to interact. Interactions may be mutually excitatory such as in the case of an instance unit and its related properties. However mutually inhibitory links also exist for example between property units whose values are incompatible and also between instance units so that there is not an overload of activated memories. This model has been illustrated by imagining two gangs; the 'Jets' and the 'Sharks'. The objects are individual members of the gangs who are each assigned a value for a given property along the lines shown in Table 1.1. Figure 1.3

Table 1.1 A sample of the individuals belonging to two gangs together with their hypothetical characteristics. (Adapted from McClelland, 1981.)

Name	Gang	Age	Education	Marital Status	Occupation
Art	Jets	40's	J.H.	Sing.	Pusher
Lance	Jets	20's	J.H.	Mar.	Burglar
Ralph	Jets	30's	J.H.	Sing.	Pusher
Sam	Jets	20's	COL.	Sing.	Bookie
Rick	Sharks	30's	H.S.	Div.	Burglar

shows how information relating to the sample of individuals specified in Table 1.1 is represented as a network. Each of the individuals is represented by an instance unit (centre) which is linked to its respective property units. The links consisting of mutually excitatory connections (shown by double-headed arrows) allow the activation of one unit to lead to a pattern of activation across the other units. If, for example, the name unit "Art" is activated then a pattern of activation corresponding to Art's properties is produced. This pattern of activation effectively amounts to a representation for Art. It is worth considering a further example; the activation of the property units "40's" and "pusher". "40's" activates the instance unit for the individual "Art" while "pusher" activates two instance units; those for the individuals "Ralph" and "Art". Of the two "Art" is activated more strongly and in turn the name unit "Art" most strongly activated. By extending this reasoning it is possible to consider the outcome of activation resulting from an input which to an extent

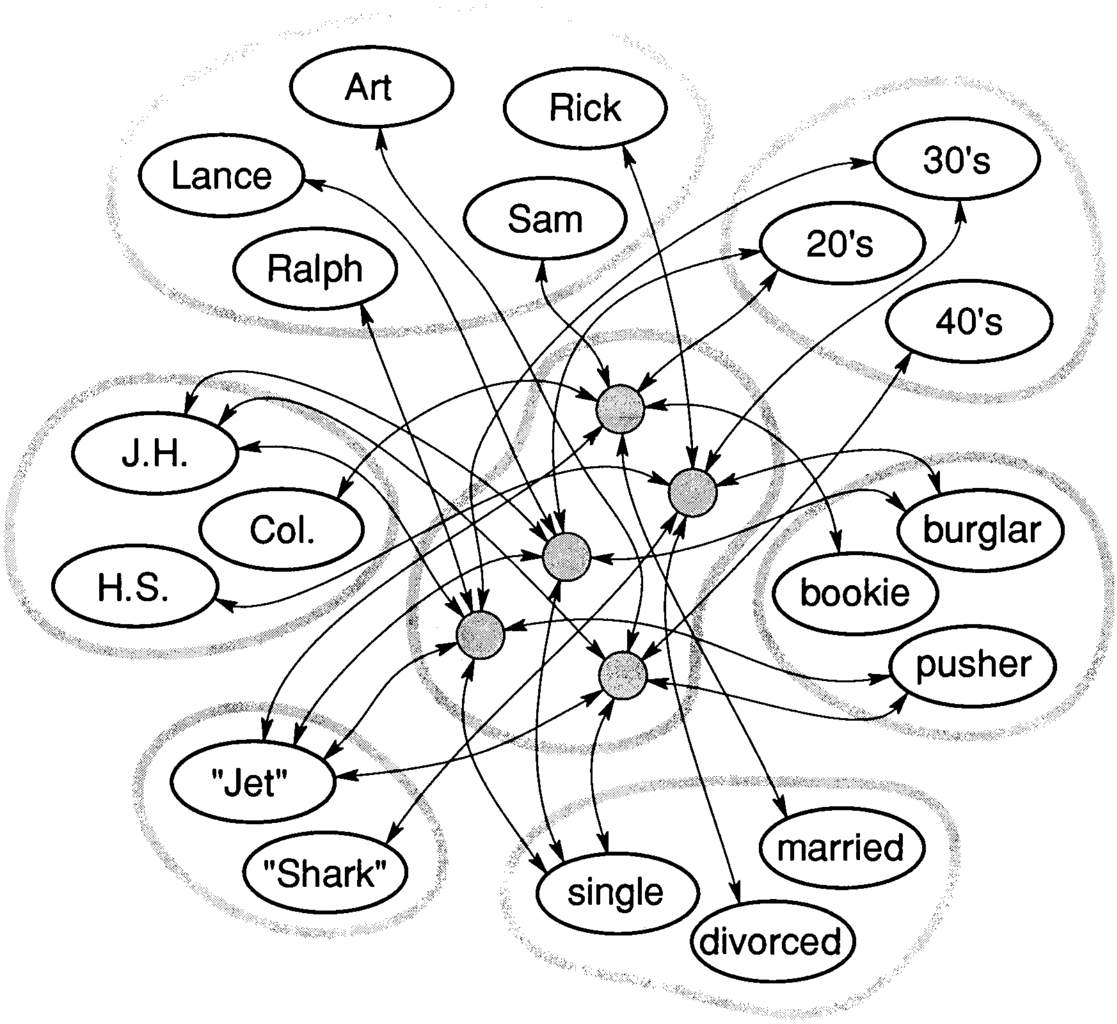


FIGURE 1.3 A network containing instance units and property units. Mutually excitatory connections (shown by double-headed arrows) occur between some units in different groups while all units within the same group are mutually inhibitory. (Adapted from McClelland, 1981.)

matches a particular object but contains some misleading properties. Rather than the misleading properties necessarily leading to a total failure in recall the instance unit or nodes best matching the input will be activated most strongly, although probably by a smaller margin in comparison to a situation where there are no misleading cues. The important point to be drawn from this is that no special mechanisms are required to deal with erroneous cues or even incomplete cues during the process of recall.

A further consequence of this network arrangement is that stored representations of an object that are initially incomplete can be enhanced in the sense that information can be interpolated as a result of subsequent partial activation of objects with similar properties. Such interpolations may, of course, be erroneous but would nevertheless occur automatically. An example of this effect in the case of the Jets and the Sharks would occur if the instance unit for 'Ralph' were to become activated but it was not known to the memory system that he was a pusher. Should, however, other individuals with Ralph's qualities tend to be pushers as opposed to burglars or bookies then, as the respective units became partially activated, the value 'pusher' for the property unit relating to Ralph would also become activated to a higher degree than the other possible values. The same type of process can also produce a pattern of activation representing properties that are general to a group rather than specific to an individual. For example activating the property unit 'Jets' will result in partial activation of all examples of Jets and a collective partial activation of property unit values will ensue. Such values as "20's", "Sing." and "J.H." may, for example, dominate while the level of activation for any one name unit is likely to remain low since most of the individuals in the gang will probably have different names. The model as described above depends upon instance units each storing a set of connection strengths relating to each object. The possibility has been also considered (McClelland et al., ibid) that the nature of stored connection strengths can be further generalised so that instance units are not a requirement. The information relating to the stored connections for any object may well be distributed over the connections for a large number of processing units rather than being confined to a single instance unit.

One thing that characterises PDP models is that patterns of activation are produced according to the particular process in hand. Patterns of activation are not stored as such but are created or recreated. In such a system the processing mechanisms do not require reference to a long term memory store so that memories have to be found and put into a working memory store in order to be implemented, instead the processing mechanisms and property units are as one and memory is effectively part of processing. A further consequence of this model is that a store of general rules which underlie the processing of particular instances does not as such exist, the system simply behaves as if it knows the rules. Learning thus does not depend on the formulation of rules but instead upon an accumulation of connection strengths.

McClelland's model is of interest in relation to the semantic structures associated with spreading-activation models. A question which arises in the present research concerns the nature of a semantic representation. This may be considered through taking an example of an everyday object such as a cup. In hierarchical information-processing models the semantic representation of 'cup' may be seen as a 'distillate' representing in abstract terms the notion of 'cup'; perhaps in terms of its possible functions and its possible manifestations as a concrete object. There would be a marked distinction between the abstract nature of this general representation and the representation that may be formed in the case of a particular instance of a cup; here a lower-level representation of various features, perhaps representing the topography of the object, may hold. In the context of a model such as McClelland's (1981) the semantic representation of 'cup' is fundamentally different; access to any one of a variety of properties pertaining to 'cup' simply serves to elicit other related properties; no formal 'distillation' of 'cupness' is stored as a separate unit. In PDP terms, then, a semantic representation is not an invariant or definable entity. If semantic representations are not readily definable as entities then in turn the nature of a semantic structure such as that proposed by Collins and Quillian may also be difficult to determine. Furthermore this logic may in turn have implications regarding the hierarchical nature of information-processing.

The modular Nature of Mental Processing

Some of the models that have already been discussed imply the existence of groupings of mechanisms or 'modules' dedicated to particular types of task. The various 'layers' of demons in the Pandemonium model may be construed as one example where processing modules are arranged hierarchically while the notion of a 'mental lexicon' or a set of stored word-representations may be thought of as a module in an overall comprehension system. Since both input and the products of mental processing may assume a variety of forms it is conceivable that there may also be a variety of processing modules together with ways in which they may be arranged.

Before the existence and possible arrangements of modules is discussed it may help to identify a general issue concerning such subdivisions of processing. Although originally written in a clinical context Geschwind (1968) has neatly outlined this issue: '...there have been schools of thought which have stressed the importance of thinking of the patient as a whole, seeing his responses as those of an integrated unitary structure, even in the face of damage. ....many confusions about the patient in our own minds as well as those of others resulted from a failure to do the exact opposite ....to regard the patient as made of connected parts rather than as an indissoluble whole' (p. 637). The idea of modularity has also been expressed through evolutionary studies. For example Jerison (1973) puts forward a view that audio-linguistic and visual-spatial processing have independent evolutionary histories. Psychological texts, especially those concerned with language comprehension, are extensively populated with models based on modularity. Also Posner (1969), for example, uses the term 'isolable processing system' with reference to internal codes of a stimulus that can be independently manipulated. Dividing the world into different parts may be argued to be limiting if the parts continue to be treated in isolation and permanent boundaries are built-up. However if the parts are to have a role in the investigative process then this process may be enhanced if interactions between what might be considered to be separate domains are also investigated. The recent study concerning the interaction of colour perception and word-recognition carried out by Prinzmetal (1990) is, perhaps, illustrative of this.

Support for some forms of modularity has been drawn from the study of people suffering from selective agnosias such as prosopagnosia (the inability to recognise faces). Hécean (1981) has noted that although prosopagnosiacs may be unable to recognise familiar faces they can usually recognise words. Ellis & Young (1988) have similarly found that the recognition of objects may not only be disrupted independently of words but also independently of faces. As these clinical conditions are typically linked with localised brain injuries it has been assumed that face, object and word-recognition systems even if not entirely different in operation may at least be separable into distinct relatively independent systems. However some caution is appropriate; face recognition is a complex task, this may be indicated by some of the reported difficulties in inter-racial face discrimination (Malpass & Kravitz, 1969). On this basis most people are capable of displaying the symptoms of prosopagnosia. If a face is regarded as a complex object and, furthermore, recognition of particular faces requires making fine discriminations among complex objects which in some ways exhibit similarities then it could be argued that the notion of prosopagnosia has arisen from special circumstances regarding the difficulty of the task rather than the content of the task object and therefore does not exist as a pure condition. It is thus predictable that if prosopagnosiacs are given tasks involving numbers of similar but complex objects other than faces then their performance would also be inferior to that of normals. Since this prediction is supported by studies carried by those such as Damasio, Damasio, and Van Hoesen (1982) and Bornstein (1963) it has been argued that face recognition systems do not exist as such and that prosopagnosiacs merely have a general loss in ability to make fine discriminations among complex objects.

Parallels may be drawn between the sophistication of most people's face recognition abilities and other forms of object recognition. In the same way that practice in discriminating between face types that we are frequently exposed to may lead to the formation of a sophisticated supporting face representational system it is also possible that extensive practice involving other objects will lead to similarly sophisticated systems. An examination of certain trades or professions where varieties of a particular object type are constantly being dealt with may also support the idea of the ability to acquire an appropriately sophisticated system. Gibson (1969) for example has noted the accuracy and rapidity with which the sex of newborn chicks can be determined by some farmers in comparison to a layperson who can only do this with great difficulty. Although the term 'representational system' is used in reference to particular enhanced discriminatory abilities this should not imply that such systems exist as functionally and topographically distinct entities. The fact that they appear to be acquired through experience in a variety of content areas suggests that the existence of separate, content-dependent 'boxes' within our mental architecture is unlikely. The underlying nature of such representational systems and the inherent mental processes may be the same; despite the apparent deficiencies relating to specific content areas exhibited through some clinical conditions it may be argued that there exists a general mechanism which is capable of supporting the processing of a variety of complex object types, and, that with practice the processing of certain groups of stimuli may be enhanced.

Word and Picture Processing

Although there are difficulties regarding the existence of mechanisms for the processing of certain object types the broader issue concerning localisation of function with respect to linguistic abilities and visuospatial abilities is one that is currently the focus of much debate. Such an issue may be relevant to any contextual effects that may arise from the concurrent processing of visuospatial and linguistic input and will therefore be further examined. For ease of reference the verbal and visuospatial categories of information are often, if not crudely, referred to in terms of words and pictures. One question, for example, which may present itself concerns whether verbal input is processed by the same mechanisms as nonverbal input.

A variety of empirical work suggests that words and pictures are processed differently. Such differences are implicitly supported by the extensive literatures that concern themselves exclusively with word-recognition or exclusively with various forms of object or picture recognition. Studies concerning hemispheric lateralisation also claim to provide evidence of a topographical distribution of linguistic and visuospatial functions. One area of work which illustrates this is the use of tests which purport to measure a variety of abilities on brain damaged subjects. If a test such as the Wechsler Adult Intelligence Scale (WAIS) is used in cases of progressive widespread brain damage (such as Alzheimer's disease) then performance on all subtests representing a range of abilities deteriorates with time. If, however, performance on subtests is correlated with the position of localised brain lesions (e.g., McFie, 1975) then language impairment appears to be associated with lesions in the left hemisphere while visuospatial impairment is associated with lesions in the right. Another finding from this work which is of particular relevance to the performance of tasks based on object recognition is that while the level of performance on one set of skills (e.g., linguistic) may be greatly impaired, performance on the other remains largely unimpaired.

Theories such as those of hemispheric lateralization, although not without their critics, may have been influential in the formation of models of word-recognition which appear to have evolved quite separately from those of object or picture recognition. This of course is not to preclude interactions between any such proposed linguistic and visuospatial systems. If words and pictures are processed differently it may be worth considering exactly what distinguishes words and pictures and how the processing of these different forms of information may coexist either on an independent or interactive basis. Analyses of any interdependencies that may exist among the processing of words and pictures has been approached through the nature of the way words and pictures may be represented mentally.

The nature of mental representations may in turn have consequences for the nature and organization of memory as well as for perception and performance. As far as the modularity of language processing and picture processing is concerned two main arguments relating to reresentational systems prevail. One is where different and independent representational systems exist according to form, and the other is where the semantic content of both words and pictures shares a common representational system. The two differing approaches have been expressed in terms of 'single-encoding' and 'dual-coding' models[1].

Single-Encoding

One notion of long-term memory that has been developed by Norman, Rumelhart and the LNR Research Group (1975) is that of a common system in which both pictorial and linguistic information may be represented in the same form. Representations are considered to be propositional, that is, our knowledge of objects and concepts is considered to be represented as a collection of symbols (not necessarily verbal) whose form in relation to any physical manifestation of the outside world is quite arbitrary. Among the arguments put forward in favour of such a 'central semantic' model is that information about the world arrives in memory via a perceptual system. If perception is seen to be the constructive and interpretive process that much of the work carried out in the area would have us believe then stored information must also reflect this interpretive and constructive nature. Although we may have the ability to image objects from memory this does not necessarily mean that information is stored in that form. An image should not be equated with a video tape of a particular sensory experience even though it may appear to be complete and continuous; it

[1] For convenience it will be assumed here that the input resulting from picture stimuli may be treated in a similar way to input arising from other environmental objects, and so both types of input will be referred to as pictorial. However this is not to deny the special status that the processing of pictures may have in relation to the processing of objects (see, for example, Hagen, 1978).

is a mutable entity in the same way that our perceptions are mutable. When appropriate we may process things using images which are regenerated from a propositional store and the nature of those images (including any conceptual errors contained therein) will reflect the nature of the store. The possibility of propositional representation for pictures maps neatly with the representation of verbal information and this in turn opens up the possibility of the existence of a single storage system within which both verbal and pictorial material may be represented. The representations within such a singular encoding system have also been assumed to be semantic in nature.

One study that has been used to provide empirical support for a central semantic processing system was carried out by Young, Hay and Ellis (1985) who examined the written accounts of 22 subjects who monitored their own problems in person recognition. The problems that frequently occurred included the complete failure to recognise a familiar person, mistaking an unknown person for a familiar one, inability to remember the name or normal context of meeting in the case of slight acquaintances who were met out of normal context and finally the inability to remember a person's name. What is interesting in the latter case is that in at least 90% of the occurrences information relating to such things as occupation or normal meeting context could be recalled but not the name. Young et al. accounted for these findings by postulating three separate processing systems; a 'face recognition system' containing a store of representations of familiar faces, a 'semantic system' containing general information relating to an individual such as occupation or normal meeting context and finally a system containing a store of words that may be retrieved in a spoken form. When it comes to considering how the above systems might be arranged the findings on the absence of certain types of problem have been of help. For example the situation where both a face is recognised and the corresponding name remembered but other semantic information is not recalled seems never usually to occur. From this it may be deduced that there is no direct route from a face recognition system to a word store; the semantic system appears to be a necessary link. Since decisions regarding the familiarity of names alone and faces alone can be made but apparently one cannot evoke the other without inclusion of semantic information then there is also a possibility of a two way traffic between these systems. Figure 1.4 presents a possible arrangement of the suggested systems based on the above assumptions.

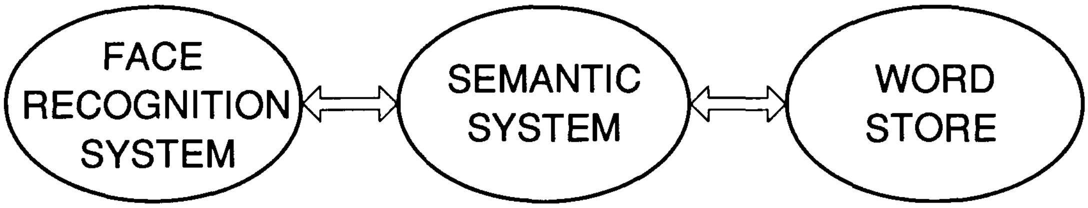


FIGURE 1.4 Mental processing mechanisms and their arrangement as implied by the introspective monitoring of problems encountered in person recognition recorded by Young et al., (1985).

Although it has already been argued that the existence of a recognition system specifically for faces as opposed to the recognition of any visually presented objects is open to doubt the above model may nevertheless be taken to be one example of a category of models which may be generalised in terms of visuo-spatial and verbal processing. One example of a more general model within which the arrangement arising from the work of Young et al. (1985) may be subsumed is the 'sensory-semantic model of picture and word-encoding' which has evolved from the work of Nelson and his co-workers (e.g., Nelson & Brooks, 1973; Nelson, Reed & Walling, 1976; Nelson, Reed, & McEvoy, 1977).

The Sensory-Semantic Model of Picture and Word-Encoding

The sensory-semantic model was evolving at a time when it was widely thought that mental processing ultimately favoured the semantic components of input while the form or 'sensory' information was progressively lost (e.g., Baddeley, 1966, 1972). In this context it was surprising to find that sensory information could affect performance on paired-associate memory tasks. For example semantically distinct but formally similar words (e.g., ban, bat, ben, bin, bit) were less effective as recall cues for numbers paired with them than words of low formal similarity (Nelson, 1968). Conversely the arbitrary association of word pairs was more easily learned if the words has letters in common, such as 'cactus-carrot' and 'instep-influx' (Nelson, Fosselman, & Peebles, 1971). Similar results were obtained with analogous experiments using stimuli where similarity in pictorial form and phonemic form was varied. (See Nelson, 1979, for a review.) Such experiments led Nelson et al. to the conclusion that pictures and verbal labels could be represented in an elaborated form both in terms of their formal, or sensory, features as well as in terms of their semantic features.

The overall arrangement of the major components of the sensory-semantic model is shown in Figure 1.5. These dominant components are systems within which features or codes relating to words or pictures are represented. The features may become activated and in this way the model has a microstructure similar to that of nodal models within which spreading-activation occurs. However the sensory features relating to words and pictures are grouped separately and in turn are considered to be qualitatively different from semantic features. The featural systems are regarded as independent; visual features representing the physical appearance of words and objects in terms of such primitives as lines, angles and brightness while semantic features represent the significance of input in terms of its denotative, connotative, associative and conceptual meanings. Phonemic features relate to the name-code of a word or object in terms of acoustic and articulatory attributes. An important characteristic of this model is that the semantic system is amodal and common to picture and word stimuli, that is, there is an equivalence insofar that the same semantic code may be activated from either a picture or its corresponding verbal label regardless of the form of input.

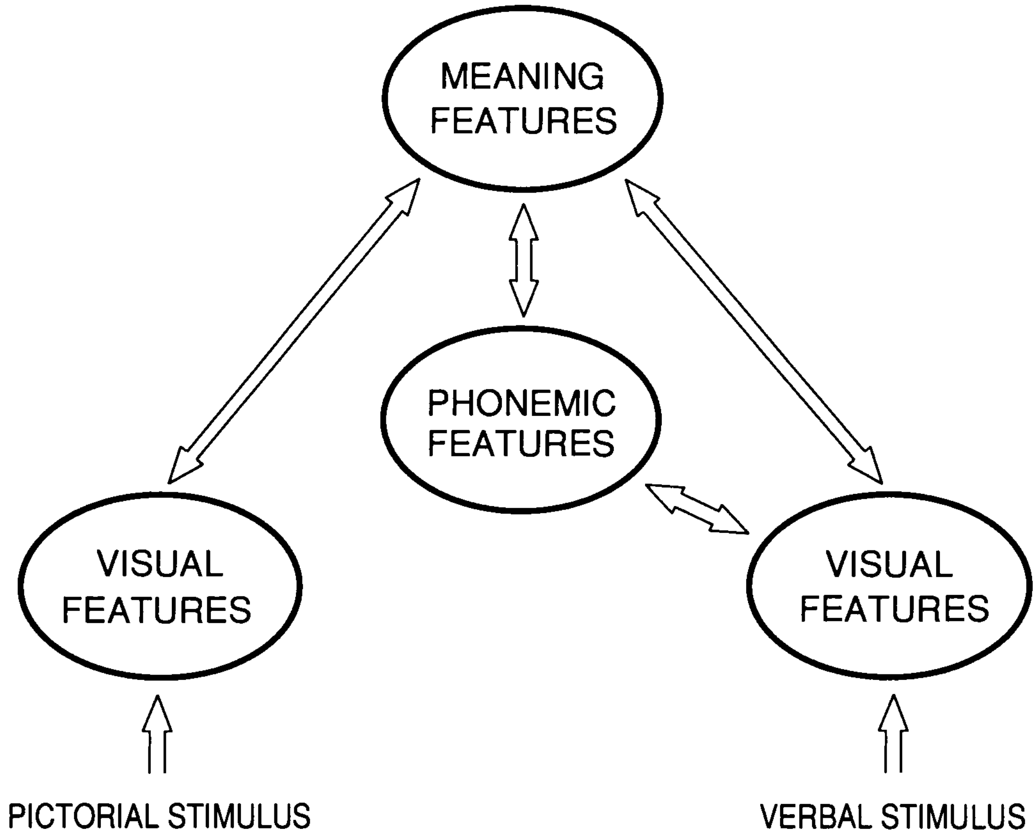


FIGURE 1.5 The sensory-semantic model of picture and word-encoding. (Adapted from Nelson et al., 1977.)

With both word and picture input processing is assumed to begin in terms of primitive visual features and more detailed visual codes are built up continuously with time as information from various types of feature is accrued. Evidence is, as it were, gradually built up; the continuation of processing is not dependent upon the completion of processing of earlier features. Similarly the processing of phonemic and meaning features is continuous and may be initiated by partial activation from a subset of the input. Although there are similarities in the initial processing of words and pictures there remains an essential difference with regard to their access to phonemic, or name-code, information: whereas this access in the case of words is relatively direct and does not require semantic mediation the same is not true with pictures; in order for a picture to be labelled verbally it has first to be identified at a semantic level.

The sensory-semantic model provides a basis from which contextual effects arising from both pictures and words can be interpreted. While containing a microstructure relating to the nodal models discussed earlier it also provides a macrostructure relevant not only to encoding *per se* but also relating to how such factors as the nature of the task or instructions allowed a selective control over encoding operations. As a result this model will be subject to further examination in relation to a range of empirical work. Before this is undertaken, however, the arguments relating to dual-coding approaches to picture and word processing will be introduced.

Dual-Coding

In contrast to the arguments for a common semantic system are those in favour of different semantic systems for picture and word input. The latter view has been represented by Paivio (1971) in the form of a dual-coding theory. The main assumption is that there are two different types of symbolic system underlying perception, memory, language and thought. A nonverbal (or imagery) system is concerned with the interpretation of scenes and the generation of images while a verbal (or linguistic) system is responsible for interpreting language and generating speech. It is also assumed that the two systems can be independent in the sense that either one or both systems can be active without interfering with each other. Among other things this assumption is derived from the comparison of interference effects on perceptual and memory tasks carried out within the same modality and between different modalities (e.g., Brooks, 1967; Byrne, 1974; Segal, 1971). The assumption that the systems are interconnected follows from such evident abilities as naming nonverbal input and generating visual images from a verbal description.

Although each symbolic system is assumed to be distinctly different the means of analysis of incoming information follows a similar form. This is evident from the adaptation of Paivio and Begg's (1981) model shown in Figure 1.6. After an initial and relatively peripheral sensory analysis it

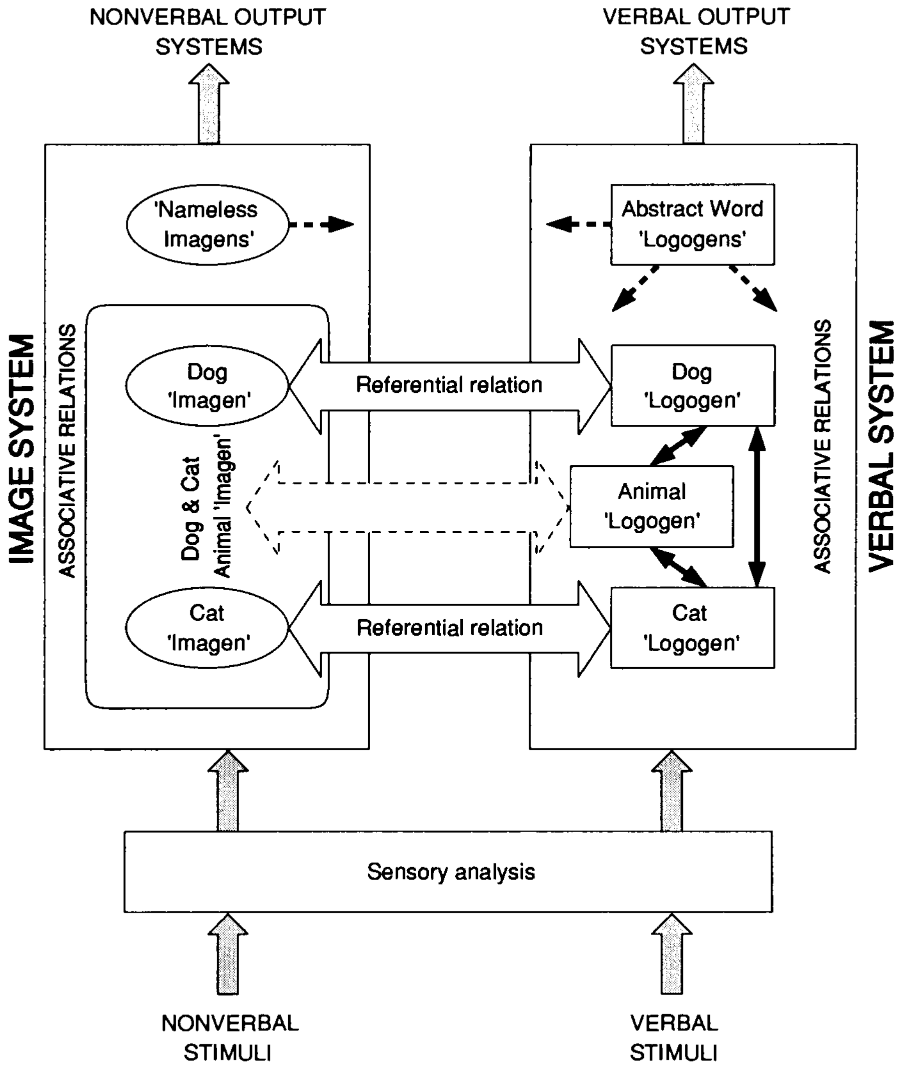


FIGURE 1.6 An adaptation of the dual-coding model of meaning. Examples are given of logogens and imagens that are known to the system. (After Paivio and Begg, 1981.)

is assumed that stimulus features are available to mechanisms which accrue information relating to known visual or verbal entities. (These have been referred to as imagens and logogens respectively. The nature of imagens may be considered to be analogous to the nature of the logogens as already described.) Upon receiving sufficient information these mechanisms become activated and enable access to further information. Access to further information may via a 'referential' link to the other symbolic system where, for example, words may be imaged or pictures named. In addition to inter-system links associative relations may be made within each system and may involve more 'collective' or 'abstract' logogens and imagens.

A further general point regarding the dual-coding model is that for each system perception and memory form a continuum. This implies that there is a degree of isomorphism between the representation of information in long term storage and the representation of incoming information. In other words information is represented in long term memory in a form which in the case of nonverbal input may be thought of in terms of such dimensions as colour, size and shape, while for verbal input the representations reflect the arbitrary characteristics of linguistic entities. Put crudely information in memory may be considered to be stored in the form of a visual code as well as a verbal code. The representation of visual code has been described as 'analogical' in nature. This contrasts with the propositional representation of pictorial information characteristic of single-encoding models. Rather than being a literal representation the term 'analogue' refers to a structural similarity between parts of an object and corresponding parts of its representing image. An analogue system may thus allow mental transformations to correspond to physical transformations; for example the intermediate views relating to the rotation of an object through a prescribed angle are also related to mental representations.

In support of dual-coding theory Paivio (1975) cites a range of work which includes experiments on size comparisons. For example Moyer (1973) has found that the time it takes to indicate a word name representing the larger member of a pair of animals varies in inverse proportion to the remembered size difference between the animals. For example 'horse-goat' would require more time than 'horse-mouse'. Such results are said to suggest that relative sizes are represented in an analogue form upon which comparisons are based. A similar experiment (Paivio, 1975) extends the comparison task to include objects represented by pictures. In addition to both picture pairs and word pairs showing the previous inverse function relating decision time and size difference it was also found that the decision time for pictures was significantly faster than for words for each of the relative size differences. Paivio assumed that analogue representations of object size are contained in the pictorial system and are accessed more directly by picture input than by word input and therefore decision times for pictures will be less. On similar grounds Paivio also argued that the faster decision time for pictures is inconsistent with verbal coding and propositional theories because if size information is stored propositionally it would be more directly accessed by words and in that case-decision times for words should be shorter. The strength of this latter argument however may rely on the assumption that word-names are recognised as quickly as picture shapes and on a further assumption that if size information is propositional in nature it is more directly accessible from a word-name than from a picture shape. This latter assumption may be questioned on the grounds that an object name is only one of a large number of attributes that may relate to an object's propositional code, therefore size information may only be indirectly obtainable from a propositional system.

Analogue Versus Propositional Representations

Many of the arguments relating to single-coding and dual- coding models concern the nature of represented pictorial information. In particular propositional representations have been contrasted with analogue representations. Pylyshyn (1973), for example, has argued strongly for a propositional store that underlies all processing. In particular he asserts that information cannot be stored as images which are latently photographic in nature because there would be no means of organized access to the inevitable vast quantity. Recalled images are therefore conceptual in nature, being constructed from abstract propositional information. Any image elements within theories on mental processes must therefore be regarded as epiphenomenal. Pylyshyn also points out the danger of equating an image with a 'picture in the head'; a picture is the final product of mental processing and not an object to be processed. In spite of the logic of the above propositionalist arguments there is, perhaps, still a need to account for the illusion of pictorial form; that is in order for images to be recreated and for the phenomenon of the picture, recourse to stored pictorial and image elements might nevertheless be necessary. Questions may arise here regarding the nature such elements and the limits of their complexity and their accessibility by means of propositional statements.

A difficulty in trying to resolve the analogue-propositional debate has been indicated by Anderson's (1978) mimicry theorem where it is argued that in principle one type of system can in most cases be designed according to mathematical or logical principles so that it accords with the effects arising from another type of system and thus a definitive proof or demonstration in favour of one particular system type over another is not to be expected. This may be illustrated in the case of the mental transformations that may result from the rotation of an object. Here it can be argued that an equivalent of the continuous process that may result from an analogue system can be obtained through discrete representations if a series of small increments are made to the relevant propositional variables. Although such a claim may appear disheartening to both theorists and experimentalists the 'narrative' may be resurrected on the grounds of what is plausible in the light of information available from a variety of paradigms or sources. These may range from neurophysiological investigations into mental hardware to behavioural studies and include such general notions as a principle of parsimony. It is within a context guided by pragmatism, then, that one may continue in an attempt to assess the virtues of each theory.

Mental Mechanisms: Some Main Themes

A variety of mental mechanisms and models relating to the analysis of verbal and nonverbal input have been briefly described. Although any given model may be subject to adjustments in an attempt to accommodate effects predictable from another competing model some major distinguishing features relating to an array of models which may be considered 'viable' have nevertheless emerged. The models discussed may be viewed both in terms of their 'microstructure' and 'macrostructure'. The notion of a microstructure may apply to the existence of such general mechanisms as processing units or nodes and the connections and flow of activity between them. In this way spreading-activation mechanisms have been contrasted with the microstructure of some parallel distributed processing models. While the possibility of facilitatory processing effects in the case of spreading-activation models the additional possibility of inhibitory effects exists with PDP models. The macrostructure of a model may be expressed in terms of such larger-scale arrangements as a processing hierarchy, or, the existence of 'modules' dedicated to processing of information in differing forms. A notable example is the possibility of a semantic system; all encoding models appear to have one. However it has been suggested that the nature of semantic representation may vary, especially where pictorial information is concerned. The possibility of representations being analogical or propositional has implications for models which have been described as single- or dual-coding with reference to verbal and nonverbal information.

The processing mechanisms and structures that have been introduced in this chapter continue to be among the objects of investigation in cognitive psychology. As indicated earlier in this chapter a comprehensive discussion of these models in relation to empirical work has so far been deliberately avoided. This was to allow the themes that have been identified to emerge rather than be submerged. Inevitably, however, further scrutiny and refinement is necessary and so some ways in which the investigation of the above issues may be focused is the subject of the next section.

INVESTIGATING MENTAL MECHANISMS

Earlier in this chapter it was suggested that mental processing is subject to the effects of context. Furthermore it was also observed that contextual effects are both pervasive and varied and the possibility of contextual effects occurring in relation to some of the mechanisms and models introduced has already been indicated. The control and measurement of contextual effects, then, may be used as an investigative device in the course of examining mental structures. This approach is, of course, not new. Within the models that have been outlined the processing of verbal content has figured prominently and so the use of printed text as an investigative medium may be appropriate. However the processing of pictorial or nonverbal content is also of interest and contextual effects relating to this may also be of interest. The commonalities and the differences between the processing of verbal and nonverbal information may also be investigated empirically through the use of text alone. In one sense a printed word is like any other object or picture, that is, without paying particular attention to its semantic aspects there remains a word-like form. The attributes that relate to this form may include colour, size, type style and case for example. In addition to such physical properties words also have a degree of orthographic regularity, a name and a semantic content. Although the processing of words is highly automatic and usually concerned with the extraction of meaning it inevitably occurs in a context where information relating to a variety of word attributes is continuously available. The converse also applies; a situation can be imagined where processing aimed at a nonverbal textual attribute occurs within a verbal context. The possibility that contextual influences may result from interactions arising from both within and between the processing of different word attributes may be considered on account of the variety of context effects that have already been established. Such interactions have typically been detected using ‘priming’ techniques. Although examples of priming have already been introduced in a historical setting further examination of what is meant by a prime may be useful in relation to present-day experimental work.

Priming

A prime is in most general terms a source of information, the availability of which may be related to an activity or activities where the results of some form of mental processing are of interest. Typically the activity is an experimental task and prime information may be presented in any sensory modality, with varying degrees of temporal and spatial contiguity to the events or objects connected with the task. Priming information may be either essential or non-essential to task performance, although the term 'cuing' (essential) has been used as distinct from 'priming' (non-essential) (Sudevan & Taylor, 1987). Experimentally, context becomes a manipulable entity through the control of prime information. Although in many experiments contextual information may be presented as a 'prime' stimulus that is separate from a 'target' stimulus upon which a task is performed, priming information may also be conveyed through a non task-relevant attribute of the target; for example with a word-naming task the priming attribute could be the colour of the ink in which the word is printed.

If the processing of a target stimulus is affected by the presence of prime information then priming is said to have occurred. Priming effects are detectable in a variety of forms; these may be physiological as well as behavioural or introspective in nature. On those occasions which involve observable performance on an experimental task response time, error rates, threshold of detection and response biasing are frequently used measures. In those studies where variation in response time is of interest the terms 'facilitation' and 'inhibition' are frequently used with reference to the speeding-up or slowing-down of responses.

Words such as 'congruent', 'incongruent', 'associate', 'nonassociate' and 'neutral' are commonly used to express the relationship that may exist between elements or attributes of the prime and target. Although these terms may be self-explanatory there are frequent occasions when further specification may be desirable. For example tables citing the frequency for word associates (e.g., Kucera & Francis, 1967) make no distinction between fundamentally different types of associates such as synonyms, antonyms and functional associates. Difficulties can arise when interpreting some studies based upon such norms where the above distinctions have not been made. Associates are potentially arbitrary in nature, although there may be a measure of general agreement as to what is an associate for a given item there may be less general agreement as to what is not an associate. Apart from associations which are formed idiosyncratically there are many occasions when it is difficult to find a nonassociate perhaps because, it may be argued, that our mental apparatus is disposed to discovering associations. It is interesting that published tables of nonassociates are not as freely available as their associate counterparts. Rather than attempt a full discussion on the problems regarding nonassociates it is perhaps best at this point merely to draw attention to this cautionary note that difficulties may occur and an attempt will be made to resolve them within the context of the empirical work that is discussed.

Perhaps a more problematic situation arises when an attempt is made to provide a 'neutral' priming condition or even to use stimuli which may be classed as neutral 'ready signals'. The inclusion of a neutral priming condition within an experiment may be a necessity in order, for example, to establish whether both facilitation and inhibition are taking place, rather than, say, just varying degrees of facilitation. Since there is a potentially wide range of information attributes available from any one stimulus the notion of a truly neutral prime is, of course, questionable. Although it may be reasonable in some experimental circumstances to dub, say, a series of priming 'X's as a neutral condition this still has to be done with caution. For example many experiments typically look at the differential effects of associated and unassociated word-primes in relation to a so called neutral condition using 'X's (e.g., Meyer & Schvaneveldt, 1971). In such cases it may be argued that the 'X's automatically prime the particular quality of non-wordness. This may have important implications for the type of processing that is under scrutiny.

Mental Models and Priming Effects

It was said earlier on that a close link exists between the questions that are asked about mental functioning and the methods employed in its investigation. In this respect the work of cognitive psychologists is no exception and the concern with mechanisms underlying mental phenomena together with the techniques involved in detection and measurement have inevitably brought their own set of questions. Some of these questions will be discussed in detail in Chapter 3 where some experimental findings relating to the processing of verbal and nonverbal attributes of word stimuli are examined. However the questions that are discussed emerged from a number of research ideas that were initially explored in relation to the present study. These will now be outlined.

CHAPTER 2

DEVELOPMENT OF RESEARCH IDEAS

In this chapter we shall look at a central theme which has pervaded the thinking behind this study; namely how a learner's behaviour may be automatically influenced by such environmental stimuli as words and pictures. At a time when much contemporary educational psychology is characterised by models of the learning process which are exclusively 'cognitive' and emphasise readily specifiable and measurable features of learning it seemed to be of interest to investigate some of the possible effects that may arise automatically from the presence of stimuli which may be outside phenomenal awareness.

One means of pursuing this area of interest was through the already established technique of 'pattern-masked' priming. In a typical experimental set-up access to conscious awareness of a briefly presented word or picture could be prevented if it was immediately followed by 'visual noise' in the form of a pattern-mask consisting of jumbled lines or letters. Many studies have used this technique in order to examine any selective influences on some overt task that might arise due to the presence of a word of picture of which the subject was unaware.

Within such a methodological context it was appropriate to ask a number of questions concerning those factors upon which the influence of a prime might be dependent. Such factors might include those relating to the prime such as its physical form or any semantic information that may be carried as well as those relating to the subject such as cognitive style, mood or mental state. Other questions arose concerning whether the influence of a prime was invariant or dependent upon individual strategy and also whether representations of events which do not reach phenomenal awareness are stored for an extended period of time and also whether these events can act as recall cues.

In terms of underlying mental processes a number of theoretical ideas were of interest. One example was Posner and Snyder's (1975) two components view of attention: a fast automatic inhibitionless spreading-activation process and a slow limited-capacity conscious-attention mechanism. Not only was this of interest in relation to Neely's (1977) results, which are discussed in Chapter 3, but also there was a link with the work of Marcel (1980) which suggested that sub-threshold primes have an activating effect relating to more than one interpretation of their content regardless of context, while supra-threshold primes have context dependent effects which are limited to one interpretation at a time. Within this context it was also of interest to speculate as to whether loci specifically responsible for the processing of such stimulus attributes as the semantic or graphemic existed, at least functionally if not spatially. With this in mind the time-course of any priming effects of different forms of information might have been of interest.

A number of experimental techniques were pursued concurrently in an attempt to replicate some of the more established findings with a view to extending the experimentation more specifically in relation to theoretical ideas such as those outlined above. Probably most time was spent in trying to obtain reliable and significant semantic-priming effects with sub-threshold words. A number of studies (e.g., Marcel, 1983; Fowler et al., 1981; Balota, 1983) have reported the effects of such primes on lexical-decision reaction time, but the results have been inconsistent. In the course of the present study a similar set of procedures was followed and similarly erratic results were obtained; if anything the results were less significant statistically than the weakest effects that were reported in the above-cited studies. Typically a sub-threshold pattern-masked prime was presented tachistoscopically and followed about one second later with a lexical-decision task in which the subject had to decide whether a given string of letters formed a word or not. Variation of such parameters as luminance, threshold setting of prime, duration of inter-stimulus intervals, density and quality of pattern-mask, size of stimuli, binocular vs. dichoptic presentation did not appear to affect the results.

A further factor which was investigated was the type of semantic-association between the prime and target: on one occasion antonyms appeared to produce a larger trend in lexical-decision latencies than synonyms, however this trend tended to be reversed in a subsequent test in which word-pairs were also categorised as category associates, functional associates and non-associates. On this latter occasion no noticeable pattern of priming effects was obtained. The experimental procedure was discussed with Marcel in his laboratory (who adopted the same priming paradigm and reported significant effects) but no important differences between the set-up and procedure used in this study and his were apparent. In addition the raw data sheets from the present research (each containing about 130 stimulus pairs) were inspected in case any other patterns of effect were noticeable. Again no obvious patterns of effect in relation to the data or the circumstances of its collection were apparent.

As such workers as Marcel (1983) and Fowler et al. (1981) appeared to have obtained large and significant semantic-priming effects with pattern-masked associates on lexical-decision tasks and since the experimental materials and procedures adopted in this study were put under scrutiny the apparent differences in outcome were puzzling. In an attempt to resolve these differences the failure in obtaining results similar to those of Marcel or Fowler was attributed either to chance on their behalf, or, to other non-identifiable factors in their experimentation. This view has been supported by recent papers. For example Merikle (1982) has suggested that the pattern-masking thresholds used by Marcel (1983) and Fowler et al. (1981) could not have been reliably estimated from the few trials run for that part of their experiments. This is strongly reiterated by Merikle and Reingold (1990) who make the additional point that the mere presence of stimulus alternatives in a recognition task such as that used by Marcel may have led to a decision-bias. A further paper (Balota, 1983) has reported the use of a pattern- masking/lexical-decision paradigm where heed had been taken of Merikle's criticisms. In this study Balota had gone to greater lengths to establish a reliable pattern-masking threshold. Not only was the threshold substantially below that obtained by Marcel (1983) and Fowler et al. (1981) but also the the lexical-decision facilitation for threshold primes was less, and weaker statistically. The results obtained in the course of the present research were similar to Balota's in those respects.

The aim of the above tests that were carried out was to produce optimal conditions for sub-threshold priming effects so that a measuring instrument capable of responding to subtle experimental conditions could be developed. However in the light of results obtained the conclusion that was drawn was that at best such techniques as pattern-masked priming on a temporally contiguous task such as lexical-decision are useable as tools but only for gross effects where one independent variable is manipulated. If finer quantitative measurements are to be attempted these techniques are unlikely to provide a sufficiently fine resolution.

In one way the lack of unequivocal results was of interest in the hope that some hitherto unconsidered aspect of the experiments might have surfaced so that ways of obtaining sub-threshold priming effects could be approached differently. In a more 'lateral' approach to this area a variety of tests were carried out on subjects in a hypnotic state (criteria: arm levitation, and analgesic symptoms). Simple reaction times were found to be longer under hypnosis than in a wakeful state regardless of encouragement to speed up. There was no reliable difference in the threshold of phenomenal awareness of pattern-masked words between subjects in hypnotic and wakeful states. Subjects who had been exposed to sub-threshold stimuli both in hypnotic and wakeful states were, under hypnosis, encouraged to recall the stimulus events as if they were in slow-motion. However the use of such an 'action-replay' or 'slowing-down' technique in an attempt at masked prime detection was without success. A Stroop colour-naming task was also tried with subjects under hypnosis: in accordance with the usual findings colour-word names were found to interfere with speeded reporting of the colour in which the stimuli were printed, but, the level of interference could be reduced to a level below that found in the wakeful state by suggesting a strategy such as only attending to the first part of a letter or word.

Various interpretations of the comparative findings for the hypnotic and wakeful states were entertained. A comprehensive coverage of these will not be attempted here; however, two ideas which featured will be briefly reported. Firstly a finding that interference on colour-naming in a no-strategy condition was enhanced under hypnosis may suggest that subjects are generally more susceptible to contextual influences and on this basis sub-threshold priming effects, if obtainable, may be enhanced in this condition. The hypnotic state was also in some ways seen as a state of relaxation and the possibility was considered that relaxed states that may be induced by other means, such as by alcohol, might also give rise to enhanced sub-threshold priming effects. Secondly the finding that threshold detection of pattern-masked primes appeared to be similar in hypnotic and wakeful states, even upon repeated presentation, resonates with an argument forwarded by Marcel (1983). Briefly this challenges Morton's (1968, 1979) and Shallice's (1972) treatment of conscious awareness as criterially dependent on a threshold amount of activation accumulated in categorisation units of particular stages of perceptual processing. Instead of awareness being conceived as qualitatively dependent on the information in these systems, Marcel argued it to be qualitatively dependent on information in a representational system specific to consciousness. His results (ibid. Expt. 5) indicate that the repetition of a sub-threshold prime does not provide the accumulation of information necessary for phenomenal representation, although lexical-decision facilitation increased with prime repetition until gradually 'levelling-out'. This can be taken to indicate that perceptual activation is not the accumulation of that information which mediates priming. The tentative findings with hypnotic subjects in the present research may also suggest that the requirements for phenomenal awareness are qualitatively different from those for non-conscious representations may also apply in an altered state of awareness, such as hypnosis.

A slightly different experimental approach that utilised pattern-masked primes was also provisionally tried, this time the emphasis being on memory. The general question concerned whether or not we remember those things of which we are unaware. Underwood's (1976, Chapter 4) discussion on attention and memory cites a number of experiments which, for example, require recall of information presented while a distractor task is undertaken. The impression gained from this discussion was that in many of the studies mentioned the 'status' of the unattended information needed to be changed in order for it to be recallable. Put another way, information which is presented in a form which is phenomenally unavailable not only has to be 'memorized' in its phenomenally unavailable 'state' but additionally has to be rendered by the subject into an overtly phenomenally available form in order for it to be expressed as a recalled item. If this point is not heeded then any interpretation of the findings may be biased towards the conclusion that unattended inputs are irretrievable. With this in mind any recall test for information of which one is unaware can only be an indirect one. Rather than, for example, expecting recall of pattern-masked words after a period of time, a more suitable requirement might be to present a pattern-masked word with a phenomenally available event (e.g., a word which is not masked) and then to see if re-presentation of the masked word aids recall of its phenomenally available episodic associate.

In relation to the above ideas an experiment involving what was referred to as 'episodic cueing' was undertaken with interesting, even if rather ephemeral, results. The experiment was based on the idea that a pattern-masked sub-threshold prime presented contiguously with a supra-threshold target might act as an episodic recall cue for the target. (The word 'episodic' relates to Tulving's (1972) conceptual distinction of episodic memory as opposed to semantic memory; episodic memory referring to the storage and retrieval of personally dated and specific experiences, compared to a more general knowledge of meanings implied by semantic memory.) A list of thirty prime and target pairs (not necessarily related) was presented, approximately three seconds elapsing between each pair. Subjects were then asked to recall as many of the target words as they could. Finally the sub-threshold primes were represented and after each prime the subject was encouraged to recall any more words from the memory set. Although in many cases no further words were obtained, or, those that were did not belong to the set there were occasions with two subjects where further words were correctly recalled and, furthermore, corresponded with the primes with which they were originally paired. Since some five to ten minutes elapsed between the original presentation and the time of correct cued recall this could be taken to indicate that some kind of representation of a sub-threshold event was stored for at least this period of time.

Although the experiment as it stood was not well controlled it was at the time considered as a possible candidate for refinement and extension and so two major modifications were made. Firstly an attempt was made to increase sensitivity by substituting cued recall with a cued forced-choice test, that is, after presenting a series of sub-threshold/supra-threshold word pairs the supra-threshold words were represented in twos with a sub-threshold cue, one of the target words being paired with that cue originally and the other drawn from one of the other pairings. No episodic cueing effects were found. Secondly, instead of using relatively 'neutral' words of high frequency of usage as stimuli, affect-laden and personally relevant sub-threshold cue words were used. Again no episodic cueing effects were found. Although some improvements or modifications might have been made with regard to the method of stimulus presentation (especially in the case of masking sub-threshold cues) the experiment was discontinued at that time.

In view of the difficulties with experiments involving pattern-masked primes there was then a shift of emphasis on to experimental paradigms where all the information contained within a given stimulus set was available to conscious scrutiny but where aspects of that information might not be consciously attended to. The main questions then became framed in terms of the extent to which information might be processed unintentionally and automatically and the extent to which that information might be retrievable, or, the extent to which that information might affect performance on a contiguous task, even though the unattended information may not be necessary for task completion.

One experiment that was piloted looked at whether a need state such as hunger might be linked to selective memorisation of items associated with hunger. Groups of about fifteen college students were used. Without too noticeable a disruption to the overall pattern of classroom activities (e.g., because some timings are informal either an early or a late lunch break can easily be contrived) an attempt was made to manipulate the likely degree of hunger. A typed list of one hundred words was presented to each subject, ten of the words signified food items, a further thirty referred to items which could be construed as examples of a container (e.g., envelope, house) and the remainder, with no obvious connection to either of these categories, were intended as distractors. A further seven words, one of which was a food item, were written on a blackboard in the corner of the classroom. The experiment was presented as a study on selective memorisation. Initially the task was to read through the list of one hundred words in order to find every word which represented a container and to try and remember it for later. After two or three hours the subjects were asked to write down as many words as they could remember from the list regardless of whether they were container words. Additionally they were asked to note any words they might have seen on the blackboard. Assessment of food intake in the intervening period was by means of a subsequently presented questionnaire within which appropriate questions relating to food were embedded.

Briefly the results tended to show a positive link between recall of food items and an assessed degree of hunger at the time of presentation of the word list. The words listed on the blackboard were used in a rough and ready attempt to assess recall of information spatially removed from attentional focus. The food item on the blackboard was not in fact recalled by any of the subjects. Because such an experiment ran the risk of inter-group contamination and because of a lack of suitable groups of subjects further investigations of this nature were not pursued.

Another experimental paradigm that was piloted attempted to manipulate word-prime processing so that different aspects of the primes would be attended to. It was thought that performance on a subsequent lexical-decision task might be affected by the nature of prime processing. A modification of an experiment performed by Henik, Friedrich and Kellogg (1983) was carried out. Two letter strings, one above the other, were presented for about half a second. The lower string was always a word while the upper was either the same word or a non-word. There was then a dark interval of about two seconds during which subjects, depending on experimental condition, would either read aloud the lower word or make a same/difference judgement relating to the two strings. A single letter string was then presented for lexical-decision. This string would either be a non-word or word semantically related to the prime, or a word not normally semantically related. The idea was that reading the prime aloud would draw attention towards its semantic aspects whilst the same/difference judgement would draw attention away from the semantic and towards 'lower-level' graphemic qualities of the word. On the whole facilitation effects on lexical-decision were stronger after the naming task and some subjects also showed significant facilitation after the same difference task. A further idea was to run a similar experiment using picture primes to see whether semantic information 'leaked through' from a picture despite attention to 'lower-level' graphemic aspects of it. This experimental approach, however, gave way to an alternative approach that was concurrently being investigated.

It was considered possible that non-task-related attributes of a prime might automatically affect performance without requiring a subject to engage in some overt attention directing task such as that adopted by Henik, Friedrich and Kellogg (1983). In view of this a series of small-scale pilot experiments were attempted using a variety of stimulus attributes such as colour, semantic category and typographic case. For example in one experiment the requirement was to use a right- or left-hand key press to indicate whether target words were in 'upper' or 'lower' case. These targets were primed either by semantic-associate or non-associate words. Since the primes were not predictive of the targets it was hypothesised that because on balance there would be no pay-off arising from conscious processing of the primes, again, any priming effects would be automatic.

In general when target stimuli presented for category decision (e.g., upper- or lower-case) are preceded by either semantic-associates or non-associates a number of predictions can be made. Firstly it might be argued that the semantic information is irrelevant to the category-decision task and thus semantic-priming effects would not be expected. Secondly it might be argued that such a previously presented associate might speed up automatic but necessary higher-level processing of the target's semantic content so that mechanisms could be freed more quickly to deal with processing content relevant to the decision task. Alternatively, the existence of a contiguously presented pair of associates might draw attention to the existence of the 'entity' of association and thus compete with attention to the category-decision task.

Case-categorisations were found to be faster when prime and target words were semantically associated, even though the associations were not related to the case-category. Similar association effects were obtained when subjects were required to categorise target words in terms of semantic-category ('animal', or 'not animal') or colour ('red', or 'white').

The latter experiments indicated that a relationship between prime and target on a stimulus attribute that was not task relevant nevertheless influenced performance. Although this finding was of interest it proved difficult to interpret in terms of the nature of any underlying mechanisms. This was also exacerbated by the possibility that with the paradigm adopted subjects might deploy different strategies concurrently (cf., Posner & Snyder, 1975). For example category-decision responses might have become contaminated with associate/nonassociate responses.

With this in mind it was considered appropriate to look more closely at any automatic priming effects that might occur across stimulus attributes but where the information carried was related in spite of the differing attributes. This, of course, has similarities to the body of work initiated by the well-known Stroop (1935) experiments (see next chapter) where, for example, speed of naming the colour of the ink in which a word was printed could be affected by the word's name. While experiments in the Stroop tradition were typically carried out using single stimuli the experiments that were being developed currently used a separate priming stimulus. This allowed for the possibility of comparing automatic effects that result from priming with a task-related stimulus attribute as well as with a non-task-related attribute. The distinct advantage perceived in this approach was that the close comparison of such 'within-attribute' and 'cross-attribute' priming effects would allow a more detailed analysis in terms of underlying mental mechanisms.

The foregoing concerns thus led to the development of a series of experiments where the separate and combined effects of within- and cross-attribute priming upon a decision task could be compared. These experiments together with their attendant theoretical concerns are reported in detail in the remaining chapters. As with the earlier experiments using pattern-masked primes the effect of unattended information on the performance on some subsequent task was being taken as a measure from which speculation concerning underlying mental processes could be made. These underlying mental processes are now considered in some detail.

CHAPTER 3

PRIMING EFFECTS ARISING FROM THE PROCESSING OF VERBAL AND NONVERBAL ATTRIBUTES OF WORD STIMULI

In Chapter 1 some of the main theoretical notions concerning the processes underlying contextual effects were introduced. These notions provided a basis from which some preliminary investigative work was conducted and could be interpreted. This preliminary work has been outlined in Chapter 2 and a theme common to much of this work was the automatic effects that context may exert. The purpose of the present chapter is to examine in detail the processing mechanisms already introduced in relation to some studies where priming has been used as an experimental tool. Through these studies further attendant theoretical issues are also introduced. Importantly in this respect the processing system is also taken to include those mechanisms that may underlie responding. This extends the discussion in the first chapter where the focus was on the representation and encoding of input.

Since the performance of an experimental task may require some form of deciding and responding any detailed analysis of experimentally obtained contextual effects must take these aspects of processing into account. At this stage a number of questions arise in relation to deciding and responding processes. For example whether or not any mechanisms implied are distinct and autonomous in relation to encoding processes is a fundamental issue. Another related issue concerns whether deciding and responding processes may be distinguished from encoding processes in terms of their automaticity, or, being subject to conscious control. The similarity or dissimilarity of any contextual effects that may result through the processes of encoding or deciding and responding may also need to be established. The task of investigating these issues is not easy;

primed letter-matching experiments. The prime (also acting as a warning signal) consisted either of a single letter or a plus sign. This was followed 500 msec later by a target which consisted of a pair of letters which required a decision concerning whether or not they matched. In this experiment there was an equal probability of a letter prime matching one or more of the target letters. It was found that decision times for matching letter pairs was 85 msec faster if preceded by the same letter (e.g., 'A' followed by 'AA') than if preceded by a different letter (e.g., 'B' followed by 'AA'). In comparison to decision times when the plus sign was used as a prime it was found that the congruent condition was 71 msec faster and the incongruent condition 14 msec slower. Posner and Snyder termed these effects as facilitatory and inhibitory respectively on the assumption that plus-sign priming was effectively neutral.

In a variation of the above method Posner and Snyder (ibid.) manipulated the probability of the recurrence of the prime letter within the target. This was in order to investigate the idea that active conscious expectational effects and automatic effects may be distinguishable. If, within a series of trials, it is arranged that the prime letter relatively frequently recurs within the target then a conscious strategy where the prime is attended to may provide certain benefits when the target is processed since on average one or more of the target items will be expected. If on the other hand the prime letter is a poor predictor of the target elements then less attention may be paid to it since on balance few benefits will accrue. When trials were presented with an increased probability (80%) of the prime letter recurring within the target it was found that both the facilitation (85 msec) and inhibition (36 msec) effects (measured in comparison to the '+' priming condition) in those conditions were increased in relation to the equiprobable trials. On the other hand the values for facilitation (31 msec) and inhibition (0 msec) (similarly arrived at) were lowered when the matching probability of the prime in the same conditions was reduced to 20%. These results were taken to support the theory that, while automatic processes result in activations which can coexist for different types of input, conscious processes have for example the attempt to determine the precise nature of any experimental effects and establish a locus for them has been among the major concerns of many workers in this field. Some of the contributions that have been made in this respect are now examined.

Automatic and Attentional Priming Effects

In Chapter 1 spreading-activation was identified as a pervasive element common to a variety of encoding mechanisms. In particular one effect that would be expected to arise through the spread of activation is a facilitation of encoding of input which in turn would be detectable through a measure such as response time. Automatic facilitatory effects have been predicted by Keele (1973) on the basis that familiar items excite logogens where information about name, form and semantic content of an item is stored. Activation takes time both to build up and to decay and while a logogen is currently activated any further incoming information that has properties in common with the activated logogen is encoded more speedily. According to this model there is a certain degree of independence among logogens with the effect that many may be concurrently activated with the current activation pattern having no inhibitory consequences as far as other input is concerned. Although the above activation pattern is considered not to be under conscious control and likewise all its products may not become the subject of conscious attention there is, according to Posner and Klein (1973), a change which takes place should conscious attention be given to any of the activated information. Conscious attention is seen as a limited capacity device so that attention to one information item, or its respective logogen, should have inhibitory consequences for the processing of others.

Differentiating Automatic and Attentional Priming Effects

In an attempt to differentiate between automatic and attentional effects on stimulus processing Posner and Snyder (1975) carried out a series of their 'costs' and are subject to limitations in capacity. For example when the primes were less likely to be attended to in the 20% probability trials only facilitatory effects (attributable to automaticity) were obtained when target letters matched; the absence of attentional effects being indicated by the apparent absence of inhibition. With automatic processing a given input results in activation that persists for a period of time so that processing of further input of a similar nature is facilitated. The processing of dissimilar input is not prejudiced since, on the basis of the logogen model, it was argued that the presence of activity in one area has no effect on the activity that may be generated in other areas. In the 80% probability condition both automatic and attentional effects may have given rise to the increased facilitation while attentional effects only would have produced the inhibition.

When interpreting the above results it may be important to keep in mind that in the 80% probability condition the prime letter predicts the occurrence of one or more target letters rather than a match between the target letters. Because of this the identities of the letters used may become a dominant factor in the task. On this basis, as Posner and Snyder have pointed out, subjects may tend to employ a matching strategy where responses are influenced by the relationship between the letters comprising the prime and target rather than on a relationship of the elements within a target. One of the effects of this may be a facilitation where all three letters are identical. However in the case of the prime letter being different from a matching target pair (e.g., 'B' followed by 'AA') a conflict may arise between responses to what are effectively competing tasks; this may result in increased response time. Further support for this line of argument was obtained from the results for the non-matching target letter pairs; within these conditions response times were shortest of all when the prime was different from both target letters (e.g., 'C' followed by 'AB'). In this situation it was presumed that the 'no' response was reinforced from the prime-target mismatch as well as the within-target mismatch. On this basis, then, facilitatory and inhibitory effects may have arisen for reasons other than those originally suggested. This limitation may be relevant with reference to the apparent lack of inhibitory effects obtained in the low probability condition. The effect of the neutral prime may be important here; whereas letter primes can both match and mismatch targets the '+' used as a neutral prime can only mismatch. The possibility of a carry-over effect from a prime-target matching strategy to the neutral priming condition could mean that while only some mismatching target letter pairs will elicit fast responses, all matching letter pairs will be slowed due to the competing tasks. On balance over a total run of trials, then, the response times will be biased towards an increase for the 'neutral' condition; this may mask any inhibitory effects which may otherwise have been detected. Posner and Snyder's (1975) conclusions regarding the absence of automatic inhibitory effects arising from the results from the low probability priming condition are open to question on this basis.

The possibility that subjects may have difficulty containing a matching task within the domain of a target stimulus suggests that the matching paradigm used by Posner and Snyder may have certain limitations when used as a tool to examine such within-attribute processing interactions. Additionally with a paradigm such as this a problem can arise concerning the effects of probability in regard to neutral priming in comparison to other priming conditions. It has already been mentioned that Posner and Snyder's conclusions regarding the degree of facilitation or inhibition were based on assumptions regarding the neutrality of the '+' primes and their ability to produce a baseline against which facilitation and inhibition effects could be compared. While in some circumstances these assumptions may be valid there are also occasions where there are difficulties regarding the comparability of such a priming condition. This is especially pertinent when comparing 'neutral' priming across those conditions where the predictive nature of the letter primes is varied. In the 80% probability condition a prime was highly predictive of one or more letters in a target only when it consisted of a letter; the '+' prime remaining unpredictive: observance of this fact would have been inescapable to subjects. If high probability events improve reaction time (as Posner and Snyder, 1975, have pointed out, albeit in a slightly different context) then it is likely that response times for the '+' primed conditions will be slower in comparison to the letter primed conditions. On this basis, then, the full extent of any inhibition effects obtained with letter primes may not show up and facilitation effects will be exaggerated if the response time to '+' primes is used as a baseline. This, of course, may partially mask any priming effects obtained on those occasions in the highly predictive letter priming condition where the prime letter is different from a matching target pair. This probability effect may also work in conjunction with the alternative matching strategy that has already been suggested.

Time-Course of Automatic and Attentional Priming Effects

Although some problems with the paradigm adopted by Posner and Snyder have been mooted a further aspect of their work deserves mention. In a series of repetitions of essentially the same experiment as the one above, Posner and Snyder (1975) examined how facilitatory and inhibitory effects varied with prime-target onset asynchronies ranging between 10 and 500 msec. In all these experiments the probability of the prime letter recurring within the target was high so attention to the prime was likely. The main findings were that facilitatory effects (worked out in relation to a 'neutral' condition as before) increased rapidly between SOAs of 10 and 150 msec and then remained at about 40 msec. These contrasted with inhibitory effects which were not significant until an SOA of 300 msec when they remained at about 50 msec (Figure 3.1). Posner and Snyder suggested that the results of this study provided support for the idea that a benefit can automatically accrue early in processing if the predictive nature of the prime is low while further benefit but also cost may arise from later processing that may be dependent on a high probability of the prime matching the target. Put another way, if automatic benefit is attributable to spreading-activation then this is fast acting in comparison to limited-capacity attentional mechanisms. Although the above conclusions may be valid there

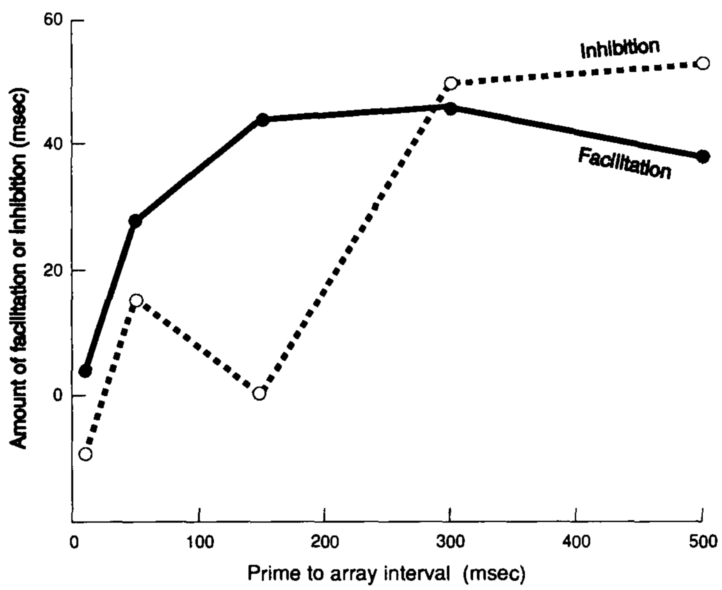


FIGURE 3.1 The variation of facilitatory and inhibitory effects with onset asynchrony between prime and target for a letter-matching task. (Adapted from Posner and Snyder, 1975)

nevertheless remains the possibility that the priming effects obtained may still be subject to an interpretation based on the consequences of the matching paradigm adopted and the debatable effective neutrality of the '+' primes used in that context as discussed earlier. This latter interpretation may be particularly relevant since in all the time-course experiments the letter primes were highly predictive of the target.

Automatic and Attentional Semantic-Priming Effects

The issue concerning automatic and attentional effects has also been investigated by Meyer and his associates (e.g., Meyer & Schvaneveldt, 1971; Schvaneveldt & Meyer, 1973; Meyer, Schvaneveldt & Ruddy, 1975). In contrast to Posner and Snyder's (1975) work which was based on physical-attribute letter matches Meyer and his co-workers studied semantic-priming effects. Two models which could account for such priming effects were proposed; a 'spreading-excitation' model and 'location shifting' model (Schvaneveldt and Meyer, 1973). The spreading-excitation model assumes the existence of a logogen system similar to that adopted by Keele (1973) but in addition account is taken of Morton's (1970) arrangement whereby semantically-related logogens are located with a higher degree of proximity than unrelated logogens. On this basis if activation for a given stimulus spreads to adjacent and, therefore, semantically-related logogens, facilitation would be expected for further semantically-related input. The location shifting model also assumes the same arrangement of logogens but this time semantic-facilitation is explained in terms of a limited-capacity, attentionally driven device which can process the information available only from a small subset of logogens upon which it is focused. If the focus is on logogens activated by a given input which is then followed by a semantically-related input then only a short period of time is required to shift the focus a 'short distance' between the related logogens in comparison to unrelated logogens which would be 'further apart'.

Although semantic-priming effects had previously been found (Meyer & Schvaneveldt, 1971), Meyer, Schvaneveldt & Ruddy, (1972; cited in Meyer, Schvaneveldt & Ruddy, 1975) attempted to differentiate between the spreading-excitation and location shifting models by requiring subjects to perform a lexical-decision on the last of three successively presented words whose semantic relationship was controlled. The crucial finding was that the response time to related-unrelated-related triplets (i.e., where the first and third words were related to each other) was faster than to unrelated-unrelated-unrelated triplets. This finding is accountable with spreading-activation if it is assumed that there is sufficient residual activation remaining from the occurrence of the first word to facilitate processing of the target. A location shifting model cannot provide an account since only the shift from the logogen pertaining to the penultimate word (effectively unrelated in both conditions) is relevant.

Meyer, Schvaneveldt & Ruddy's (1972) experiment however does not rule out the possibility that a location shifting mechanism may also act in conjunction with spreading-activation. The Posner and Snyder (1975) study for example suggests such a possibility in terms of automatic spreading-activation in addition to the limited capacity attentional mechanism which is considered to correspond to the location-shifting model. In order to investigate this possibility at word-level Neely (1976) ran a primed lexical-decision experiment where subjects' responses to the word or nonword category of letter strings were timed. An intentional feature of this experimental paradigm was that the prime-target matching strategy which might have been adopted by Posner and Snyder's (1975) subjects could be avoided. In addition to primes which were semantically-related or unrelated to their respective targets, 'neutral' primes consisting of a row of Xs were used. It was argued that the neutral prime would not direct limited-capacity attentional mechanisms or activate word logogens associated with the target. Prime-target SOAs

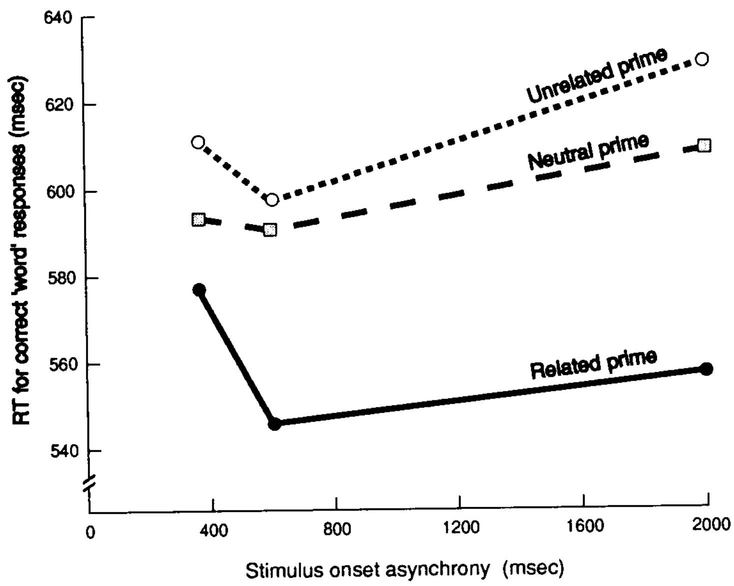


FIGURE 3.2 Lexical-decision reaction times for correct responses to word targets as a function of prime-target relationship and SOA. (From Neely, 1976)

of 360, 600 and 2000 msec were used so that any time-course of effects was also examinable. These SOAs (relatively long in comparison to those used by Posner and Snyder) were chosen so as to allow time for the prime to be read and associated logogens to be activated. The relatively large facilitation effects in relation to the neutral priming condition (shown in Figure 3.2) may be accounted for in terms of automatic spreading-activation as well as attention to prime-related logogens. The inhibitory effect obtained was also considered to lend support to the argument that separate automatic and attentional processes may be responsible for facilitation. This argument was based on the assumption that inhibitory effects do not arise from automatic spreading-activation thereby suggesting that attentional effects exist which, in addition to automatic effects, can also give rise to facilitation. This assumption, of course, is not in agreement with the inhibitory processes predictable according to the PDP mechanisms outlined in Chapter 1. Although some aspects of the results are in keeping with the general idea of a limited capacity attentional mechanism (such as the inhibitory effects obtained with unrelated primes) other aspects are problematical when considered in detail. For example there is no significant increase in inhibition with increasing SOA as might be predicted from Posner and Snyder on the basis of attentional processes being slow to take effect. However in order for this interpretation to have more weight the effects would need to be examined from earlier on in the time-course. Also of interest in the Neely (1976) findings is that, in comparison to a neutral prime, a word-prime facilitated decision reaction times for nonwords. This counters the argument that a prime word may be attention demanding in comparison to a recurring string of Xs and has invited explanations in terms of subjects matching self-generated prime associates with the target word and responding in those terms rather than in terms of lexical identity. Although Neely's results may appear to bear some equivalence to those of Posner and Snyder (1975) and in that sense may counter some of the arguments concerning the limitations of the matching paradigm adopted by the latter it is nevertheless important to note that any conclusions concerning the coexistence of automatic and attentional effects rests upon the assumption that inhibitory effects are not obtainable at stages concerning automatic activation. Since reservations concerning this latter assumption have already been expressed it is difficult in the context of this logic to be conclusive regarding the role of automatic and attentional mechanisms on the basis of the data so far discussed.

In an attempt to further investigate any differential effects that might relate to automatic and attentional mechanisms operating at the semantic-level Neely (1977) again used a primed lexical-decision task but, in a method having some parallels to Posner and Snyder (1975), now controlled subjects' expectations regarding the relationship of the prime

Table 3.1 Reaction times (msec) obtained by Neely (1977) to word targets in terms of mean facilitation (+) or inhibition (-) scores for word-prime conditions for a prime-target SOA of 250 msec. (NS-Ex-R = nonshift-expected-related; NS-Ux-U = nonshift-unexpected-unrelated; S-Ex-U = shift-expected-unrelated; S-Ux-U = shift-unexpected-unrelated; S-Ux-R = shift-expected-unrelated.)

Word-prime condition	Example	Reaction time variation (msec)	
NS-Ex-R	BIRD-robin	+33	(p<.001, two-tailed)
NS-Ux-U	BIRD-arm	+3	
S-Ex-U	BODY-door	+4	
S-Ux-U	BODY-sparrow	-16	
S-Ux-R	BODY-heart	+20	(p<.05, one-tailed)

to the target. Table 3.1 shows the five combinations he used. For example in a 'nonshift-expected-related' condition the category-word 'bird' was used as a prime and subjects were told to expect a semantically-related target exemplar such as 'robin'. Similarly in a 'shift-expected-unrelated' condition for the prime 'body' subjects were told to expect an exemplar from a building-parts category such as 'door'. Those trials where the prime category was not predictive of the target type were assigned to 'nonshift-unexpected-unrelated' and 'shift-unexpected-unrelated' conditions. In these experiments the prime-target SOA was also varied, although this time over the range 250 to 2000 msec on the assumption that this would be sufficient to observe the differences in priming effect between the fast acting spreading-activation and the slower attentional mechanisms. The results obtained were argued to be in general agreement with predictions based upon the model suggested by Posner and Snyder (1975), that is both attentional and non-attentional factors in the nonshift-expected-related condition (e.g., BIRD-robin) would contribute to facilitatory effects at all SOAs while attentional factors would facilitate at longer SOAs in the shift-expected-unrelated condition (e.g., BODY-door).

In addition, attentionally induced inhibitory effects (cost) increased with SOA in both the shift-unexpected-unrelated (e.g., BODY-sparrow) and nonshift-unexpected-unrelated (e.g., BIRD-arm) conditions. Also facilitation arising from non-attentional influences which prevailed at short SOAs was masked by inhibitory effects at longer SOAs due to attentional factors in shift-expected-unrelated (e.g., BODY-heart) condition. Thus it was argued that regardless of attention, automatic effects which facilitate performance only were in evidence at prime-target onset asynchronies as low as 250 msec while conscious attention demanding effects were slower acting and gave rise both to a facilitation and inhibition of performance which was in evidence at SOAs of 400 msec and above.

Neely's (1977) work is important in that it provides a more rigorous analysis of the coexistence of the effects of automatic and attentional mechanisms than has been available hitherto. However as far as automatic effects are concerned, although Neely argues that the results support a spreading-excitation model where any priming effects are only of a facilitatory nature the possibility that automatic inhibitory effects might also exist was never a part of his discussion. His statistical analysis although lengthy and comprehensive in many respects sought, as one might reasonably expect, to establish the probable existence of theoretically predicted effects rather than the possible existence of effects which were not predicted. With regard to this latter point, however, the possibility of an unpredicted automatic inhibitory effect is important in the wake of the principles articulated within many PDP models where an interactive encoding mechanism which has inhibitory as well as facilitatory consequences may exist. It may be argued that Neely's (1977) conclusion regarding the non-existence of automatic inhibitory effects may have arisen for two main reasons. First, the shortest SOA of 250 msec, chosen so that only automatic effects would be elicited, was not short enough to reveal inhibition. In such a case any automatic effects at 250 msec SOA might have become contaminated with attentional effects. Second, the obtained levels of significance were in general too low to firmly establish some of the predicted trends, especially at the 250 msec SOA.

Some specific illustrations regarding these reservations may help. These will be discussed with reference to Table 3.1 (Page 83) which shows the results obtained by Neely (1977) for a prime target onset asynchrony of 250 msec. The possibility that an SOA of 250 msec was not short enough to sufficiently minimize attentional effects is suggested by the differences obtained in the two Related (R) conditions; a facilitation effect of 33 msec was obtained at the .001 significance level for an expected target while for an unexpected target the smaller 20 msec facilitation effect was only just statistically significant ($p < .05$, one-tailed). Although this latter 20 msec facilitation effect was considered to support the predictions concerning the facilitative nature of automatic effects the 16 msec inhibitory effect obtained in the unrelated (BODY-sparrow) condition was discounted, yet the mean priming effects in both these conditions were not very different in magnitude, and not entirely different with regard to statistical significance (SEM=11.7, N=179 and SEM=10.6, N=179 respectively). The Shift-Expected-Unrelated condition (BODY-door) is of interest insofar that on the basis of automatic effects consistent with most PDP models only an inhibitory effect should result at 250 msec SOA. If, however, attentional effects were also present then such an inhibitory effect would either be tempered or masked by the facilitation arising due to a target outcome congruent with expectation. The non-significant 4 msec facilitation effect obtained in the latter condition does not rule out the possibility of a 'hidden' automatic inhibitory effect particularly in the context of the other findings in respect of the temporal onset of attentional effects. Finally although the non-statistically significant 3 msec facilitation obtained in the nonshift-unexpected-unrelated condition (BIRD-arm) is more consistent with automatic effects which are facilitatory-only, rather than also having the capacity to be inhibitory, the possibility of a type II error cannot be ruled out. In sum it may be argued that while Neely's (1977) data accord with an encoding mechanism that is based on spreading-excitation they do not exclude an alternative possibility that an automatic encoding mechanism incorporating inhibitory as well as facilitatory processes may exist.

Discrete Processing Stages

A number of interrelated issues have emerged from the empirical work so far discussed; in particular the existence and nature of automatic and attentional priming effects. Although the possible mechanisms underlying such effects may have been implied this issue has so far not been addressed directly in relation to extant experimental data. An approach adopted by a number of experimentalists has been to assume that functionally separate mechanisms are responsible for different mental processes. This approach has already been discussed in Chapter 1 where the modular nature of encoding was the reference. A similar grouping of mechanisms associated with encoding and responding may also be argued. For example with Posner and Snyder's (1975) letter-matching experiments the obtained relative increase of facilitation with probability may suggest that automatic and attentional effects may be at least partially additive. This in turn may suggest that independent processes are involved. Although such an approach may be attractive it is not without its dangers. This may be exemplified by some classical work carried out last century by Donders.

Donders (1868) attempted to investigate the underlying mechanisms involved in choice reaction time by running three types of experiment.

One experiment involved the measurement of simple RT (condition a), another involved the presentation of any one of five stimuli, each requiring its own specific stimulus-related response (condition b), while a third involved the presentation of five different stimuli, only one of which required a response (condition c). Response time was shortest for simple RT and longest for the choice task (b) which involved five distinct stimulus-response pairings. In order to explain his findings Donders assumed the processes of discrimination of a stimulus and the choice of a response were separable and did not vary between experimental situations. A further assumption was that the time occupied by each of these processes could be related to the overall response time by simple rules of addition and subtraction. Thus, as the 'b' condition involved both discrimination and choice while the 'c' condition only involved discrimination the choice time could be arrived at by subtracting 'c' from 'b'. Similarly by subtracting 'a' from 'c' the discrimination time was obtained.

Although this 'subtractive' method introduced by Donders has enjoyed popularity it does not necessarily provide a tenable account of underlying processes. Some of the problems which arise when attempting to interpret these findings include the fact that the 'c' condition does not necessarily exclude response selection; the subject has still to decide whether or not the stimulus is the target. Another problem is that the response processes for a simple RT experiment may involve quite different strategies from those in a choice RT experiment. The principal difficulties arise from the possibility that complex processes cannot always be considered to consist of a simple summation of elements and that different processes are not necessarily governed by a temporal seriation which leads to simple subtractive rules; processes may overlap in time and furthermore the involvement of new elements on one task may cause changes in the functioning in the other elements involved in the other condition. In other words it cannot be assumed that, if any processing stages exist, they will function independently of each other.

Although Donders' original treatment may be too simplistic some of his ideas underlie more recent work. An important revision of the method used by Donders was carried out by Sternberg (1969). Subjects were asked to memorise a list of letters and then they were presented with a probe letter. The time that it took to decide whether or not the probe was in the list was measured. Lists of varying length were used and the results showed a linear relationship between the reaction time and the list size. The postulation of a serial search process of items in memory seemed reasonable. One thing that was found from the results was that the search time per list item was the same regardless of whether the probe was drawn from the list. This suggested that the search was exhaustive. The key difference between this method and that used by Donders is that it investigates the number of times a given process operates, not whether the stage is present or absent.

Taylor's (1977) Study

Taylor (1977) also assumes the existence of a series of discrete processing stages. These are shown in Figure 3.3. The 'feature extraction' and 'pattern identification' stages have, by Taylor, been collectively referred to as 'stimulus processing'. Similarly 'response determination' and 'motor activation' have been referred to as 'response processing'. It is assumed that these stages operate serially and that reaction times may be determined by the addition of the processing times required for each stage. This stage model provided a base from which Taylor could infer and investigate mechanisms underlying context effects. Experiments were devised which attempted to influence the processing in certain stages selectively; pairs of successive stimuli were used, one provided context (effectively a prime) while the other acted as a probe (or target) and required a response. The logic was that if these stimuli are manipulated in terms of their relationship and onset asynchrony then measurement of response times to the probe may lead to inferences concerning the processes that may occur at the relevant stages. Taylor (1977) used single-letter stimuli and Figure 3.4 (Page 91) gives an

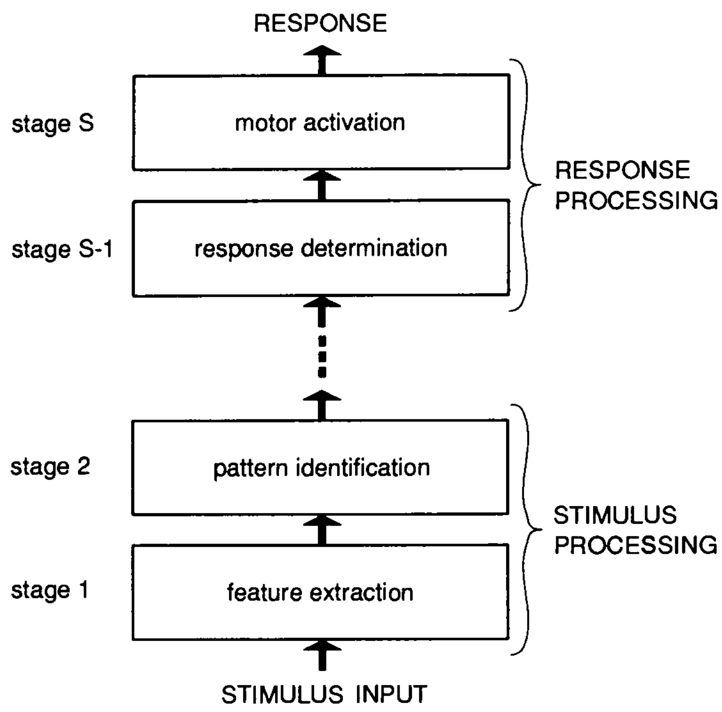


FIGURE 3.3 Processing stages and their arrangement. (Adapted from Taylor, 1977.)

indication of the form of a typical experiment. This work will now be examined in detail since it provides some interesting analytical viewpoints. Because the interrelationships between the varieties of possible priming effect occurring within different mental mechanisms are relatively complex and the data therefore subject to different interpretations the discussion of Taylor's work is correspondingly lengthy. However its importance in relation to the present study is signalled here since the work provides some useful bases for further investigation.

General and Specific Effects

The processing of two stimuli rather than one may be viewed in terms of limited processing resources having to be shared. According to Taylor (1977) a so called 'general effect' on the processing of one stimulus may arise as a result of the processing of the other. This general effect may occur regardless of any relationship between stimulus content and has been likened to the psychological refractory effect (Appendix 1).

In contrast to such general effects it was expected that 'specific effects' would result from varying the relationship between probe and context. The relationship between stimuli may be determined by such factors as similarity of content or the responses assigned to them. Specific effects can be investigated by comparing one or more types of experimentally determined context-probe relationship with a control where the context is said to be neutral. Since it was assumed that a neutral context would produce the same general effect as an experimental one specific effects were considered to be deducible.

Among the types of specific effect that may arise Taylor (1977) has made a further distinction between 'primary' and 'secondary' effects. A primary effect can be illustrated by considering the fate of two stimuli presented simultaneously; here it may be argued that, providing the same processing stages are encountered and the stimuli processed in an equivalent manner, the effect of one stimulus upon the other will be reciprocal so that both stimuli are processed through the same stages at the same rate. In general it is conceivable that to an extent the processing of two stimuli, even if presented at slightly different times, will lead to mutual or reciprocal interactions that would produce a time-course of effects symmetrical about an SOA of zero. Secondary specific effects are considered to arise due to the completed processing of an initial stimulus on the processing of a subsequent stimulus. For example if two successively-presented stimuli are identical then the first stimulus may leave the processing system 'tuned' for a short period of time so that the processing of the second stimulus is speeded. Although the effect of this may alter any internal SOA-gap that may exist between the stimuli Taylor argues that the influence of the context on the target processing is unidirectional rather than reciprocal. In terms of a time-course, secondary effects would be expected to show up asymmetrically about a zero prime-target onset asynchrony.

As did Posner and Snyder (1975), Taylor (1977) used single-letter stimuli, but instead of a matching task a choice-decision task was used.

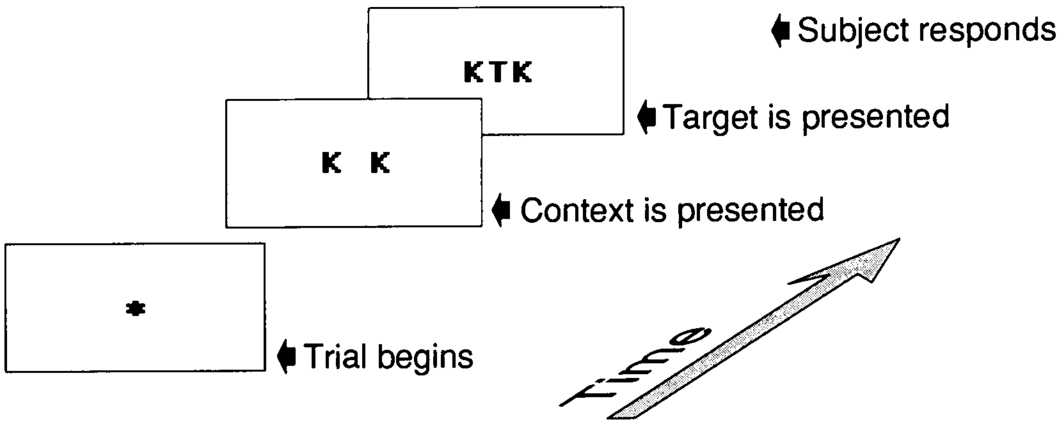


FIGURE 3.4 An example of the stimuli used and the sequence of events comprising a single trial in Taylor's (1977) Experiment 1. Subjects respond with a right-hand key-press if the target letter is 'T' and a left-hand key-press for a target letter 'K'.

Subjects were required to press a left-hand response key on the occurrence of the target letter 'K' and press a right-hand key for the letter 'T'. In Taylor's first experiment (again see Figure 3.4) a trial consisted of a target letter presented centrally within and temporally contiguous to a context which consisted of two representations of the same or another letter. In all there were three experimental conditions. In one condition both target and context consisted of the same letter (e.g., 'KKK'), in another the context letter was the same as that assigned to an opposite key response to that of the target (e.g., 'TKT') while in a neutral condition the context consisted of a letter that was not used as a target (e.g., 'OKO'). When the context was presented after the target no significant facilitatory or inhibitory effects (apart from one small inhibitory effect occurring at a 50 msec separation) were detected over the 250 msec stimulus onset asynchrony range used. When the context was presented simultaneously with or preceding the target, however, significant facilitatory and inhibitory effects were obtained; these reached a peak with an SOA of 50 msec and thereafter decayed with increasing SOA over the 250 msec range used. These results are summarised in Figure 3.5. Because primary specific effects were assumed to be symmetrical about an SOA of zero Taylor (1977) attributed the facilitation and inhibition obtained above 0 msec SOA to secondary specific effects.

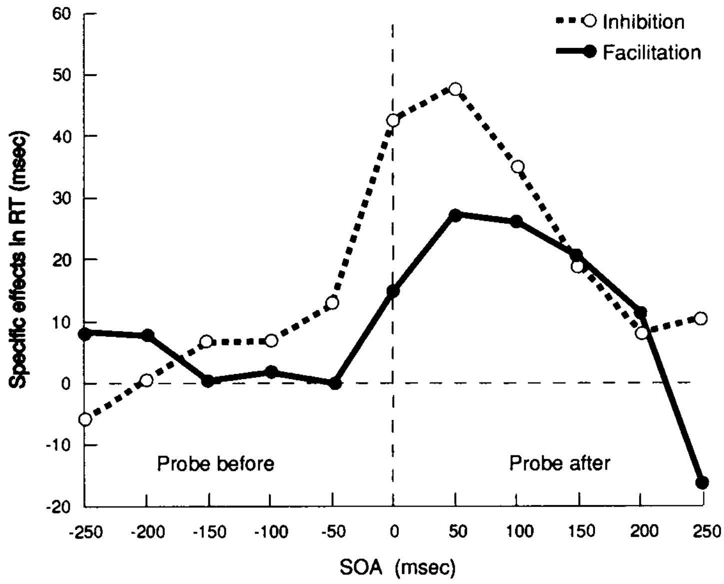


FIGURE 3.5 The time-course of the variation in choice decision reaction time according to priming condition. 'Probe' refers to a stimulus to which a response is required. 'Before' and 'after' refer to the onset of contextual information. (From Taylor, 1977, Experiment 1.)

So far, then, from Taylor's (1977) first experiment a picture is built up of automatic priming effects on a choice-decision task which appear to arise from a temporary change in state of a processing system as a consequence of a prior stimulus rather than arising from an ongoing interaction among concurrently processed stimuli. A major point that may be observed here is that, in contrast to priming studies such as those carried out by Posner and Snyder (1975) and Neely (1976, 1977), Taylor's account acknowledges the existence of automatic inhibitory effects.

Automatic and Attentional Effects

Taylor (1977, Experiment 2) also investigated automatic and attentional context effects. To achieve this the probability of the context matching the target was varied in a similar way to that in Posner and Snyder's (1975) experiments. The results, this time only obtained for target post-exposures ('probe after') ranging from 0 to 500 msec, suggested that in addition to facilitatory and inhibitory effects similar to the first experiment there were attentional effects which were also facilitatory and inhibitory. The slope of the time-course of attentional inhibitory effects showed a decay with increasing SOA similar to that of the automatic inhibitory effects, except that the magnitude of the attentional effect was approximately twice that of the automatic effect and was accompanied by a corresponding increase in duration. By way of contrast, although the magnitude of the facilitatory effect obtained in the high probability condition was similar to that for equiprobable condition at zero SOA, the effect of high probability priming increased with SOAs up to a value of 200 msec before levelling out. Because the error rate for attentional inhibitory context was high in comparison to that produced by a facilitating context Taylor concluded that a response bias building up to a maximum at 200 msec SOA was responsible for the attentional facilitatory effect. Since a facilitating context in the attentional condition was more frequent subjects took context as a cue to the response to be made.

Locating Automatic Facilitation and Inhibition

Of particular interest with regard to the mechanisms that may be responsible for automatic facilitation and inhibition is Taylor's (1977) third experiment. A major concern at this point of the work was to attempt to assess the contribution of the individual processing stages (Figure 3.3, Page 88) to the overall context effects. To this end the format and procedure of his Experiment 2 was adopted but with an important variation: an extra letter was associated with each of the response keys. Whereas previously only one letter (T) corresponded with a right-hand response and similarly one (K) for the left-hand, this time there were two response possibilities for each hand; the letters 'F' and 'R' being assigned to the left-hand while 'K' and 'T' were assigned to the right (Figure 3.6). With this set-up it was possible to have a 'response-facilitation' condition where the context could be congruent with the response while remaining different from the target (e.g., 'KTK') and an 'inhibition' condition where the context as well as being different from the target was also incongruently related to the response (e.g., 'FTF'). The idea was that the effects that might result from the above priming conditions could be specifically related to the two main groupings of the processing stages; stimulus processing and response processing as shown in Figure 3.3 (Page 88).

F or R	K or T
Left-hand response	Right-hand response

FIGURE 3.6 Letters assigned to left and right-hand key responses in Taylor's (1977) Experiment 3.

A comparison of the automatic effects revealed that while inhibitory effects comparable with those of the other experiments were obtained in the inhibition condition (e.g., 'FTF') there were no significant priming effects in the response-facilitation condition (e.g., 'KTK'). Taylor argued that since in these two conditions the context and targets never matched the only distinguishing factor was the degree of association between context and response therefore the inhibitory effect must have resulted from response processing rather than stimulus processing. In the stimulus-facilitation condition the context and target always matched (e.g., 'TTT') and so the only difference between this condition and the response-facilitation condition (e.g., 'KTK') was the occurrence of matching stimuli since in both these conditions the context stimuli were congruent with the response. On this basis it was inferred that the locus of an automatic facilitation effect obtained in the 'stimulus-facilitation' condition was at a stimulus processing stage. This latter conclusion, however, is questionable in terms of the logic adopted by Taylor. Even if assumptions such as those concerning stages which work independently and serially are accepted, the argument that "effects of stimulus repetition ought to appear only in stages involved with stimulus processing" (Taylor, 1977, p.419) is difficult to accept in view of the fact that if the same letter is used both as prime and target then as well as being congruent in terms of stimulus processing it is also (inevitably) congruent in terms of response processing. If the 'stimulus-facilitation' condition is now reinterpreted as a 'stimulus and response-facilitation' condition then, contrary to Taylor's conclusions, it may now be argued that the obtained automatic facilitation may be attributable to either or both of the stimulus processing and response processing stages.

The possibility that inhibition could arise from a conflict at the stimulus processing stage, and, that facilitation could arise from response compatibility was also entertained by Taylor. However this was discounted on the grounds that a balance of inhibitory and facilitatory effects would be necessary to account for the net zero effect in the response-facilitation condition. This would mean that these effects should be equal in magnitude. Since Taylor claimed that the automatic facilitatory effects were on average nearly three times the magnitude of the automatic inhibitory effects the conclusion was that those results did not support such an alternative possibility. However the fact that the magnitude of automatic inhibition was well in excess of automatic facilitation for Taylor's (1977) first two experiments does not appear to have been considered in this context. Since it can be argued that the inhibition and stimulus-facilitation conditions for the third experiment are equivalent to the respective automatic priming conditions in the first two experiments then it appears that imbalance in automatic facilitatory and inhibitory effects obtained in the third experiment is not reliable. The alternative possibility where the obtained effects are based on stimulus conflict and response compatibility therefore cannot be eliminated.

A further argument put forward by Taylor with regard to the possibility of inhibition resulting from stimulus processing and facilitation from response processing makes reference to the results for the high probability conditions that were also run in the third experiment. Here the argument was considered that the difference between the 'stimulus-facilitation' (e.g., 'TTT') and the response-facilitation results (e.g., 'KTK') could be attributed to inhibition from a stimulus mismatch rather than facilitation from a stimulus match. If this were so then, the argument continues, the inhibition results should show the same trend as the net inhibition effect obtainable from the 'stimulus-facilitation' and the response-facilitation results. Since the two time-course trends were very different in magnitude and quality Taylor considered his argument concerning the implausibility of inhibition arising from stimulus mismatch to be supported.

This latter argument might have presented a deciding case if it were not for a number of other factors. Firstly the results obtained from the inhibitory condition which was used as a comparison could have arisen from inhibition occurring within responding mechanisms as well as stimulus mechanisms. Secondly, the fact that there are also other logical possibilities with regard to combinations of facilitatory and inhibitory effects within stimulus processing and response processing mechanisms. These logical possibilities will be shortly discussed. Thirdly, and perhaps most importantly, given the possibility that inhibition may arise from stimulus conflict, the status of the neutral prime is also called into question. Taylor considered the letter 'O' to be neutral in all three experiments on the basis that it was not associated by instruction to either a left- or right-hand response. While it may be reasonable to assume that 'O' is neutral with regard to response-mechanism-priming the situation, it is less clear with regard to stimulus processing mechanisms. Since Taylor uses the term 'stimulus conflict' to refer to prime-target events such as 'KTK' and 'FTF' regardless of the response congruity it may be assumed that the conflict arises due to a lack of stimulus repetition; in this case 'OTO' must also qualify in terms of its ability to give rise to a stimulus conflict and therefore cannot be regarded as a neutral prime where stimulus processing mechanisms are concerned.

Reinterpreting Taylor's Findings

Before the implications of the problem with Taylor's assumptions regarding neutral priming are further considered a framework for analysis will be presented in terms of the various logical possibilities with regard to the automatic facilitatory and inhibitory effects that may arise within stimulus processing and response processing mechanisms. Since these possibilities when presented in the form of continuous prose may be difficult to follow they are presented in the form of a matrix in Figure 3.7. Within this matrix stimulus mechanisms are represented by 'S' and responding mechanisms by 'R'. The possibility that facilitation

	R-	R+	R±
S-	S-,R-	S-,R+	S-,R±
S+	S+,R-	S+,R+	S+,R±
S±	S±,R-	S±,R+	S±,R±

FIGURE 3.7 The logical possibilities regarding the occurrence of automatic facilitatory (+) and inhibitory (-) effects within Taylor's (1977) stimulus processing (S) and response processing (R) stages. (See text.) Cell entries show each logical combination.

can occur within a mechanism is represented by '+' and inhibition by '-'; thus 'S+,R-' exemplifies Taylor's (1977) conclusion that, as far as automatic effects are concerned, only facilitation is possible in stimulus mechanisms and only inhibition is possible in responding mechanisms.

If it assumed that Taylor's findings concerning the existence of both automatic facilitatory and automatic inhibitory effects are valid then the number of processing possibilities reduces. For example an 'S-' model only allows for automatic inhibition; there is no mechanism here which would produce automatic facilitation. On this basis the 'S-' possibility can be eliminated if facilitation was assumed to occur. The 'R-' and 'S-,R-' models also predict inhibition only and can also be eliminated from the matrix. A similar argument applies where only facilitation is predicted as with the 'S+', 'R+' and 'S+,R+' models. In this way the number of automatic processing possibilities is reduced from fifteen to nine (those cells where only facilitatory, or, only inhibitory effects occur being eliminated). The surviving processing models are shown in Figure 3.8.

			R±
		S-,R+	S-,R±
	S+,R-		S+,R±
S±	S±,R-	S±,R+	S±,R±

FIGURE 3.8 The remaining logical possibilities regarding the occurrence of facilitatory (+) and inhibitory (-) effects within Taylor's (1977) stimulus processing (S) and response processing (R) stages on the assumption that both automatic facilitatory and automatic inhibitory effects are obtainable. (See text.)

One way of carrying this process of elimination further is to use Taylor's (1977, Experiment 3) finding that there were no automatic priming effects for the 'response' facilitation condition (KTK) as a reference point against which deductions concerning relative priming effects can be made. For instance, as already implied by Taylor, the apparent lack of effects could have resulted for two reasons; either facilitation and inhibition were absent, or, facilitation/s and inhibition/s of a roughly equal magnitude cancelled each other. In this context it may be reasonable to make the simplifying assumption that for both stimulus and response mechanisms congruent priming where applicable can produce one unit of facilitation and incongruent priming one unit of inhibition and that these effects are additive. With this in mind the conditions from Taylor's third experiment can be expressed 'inclusively' in terms of the possible effects on stimulus-encoding and response systems. These are as follows:

'stimulus-facilitation'	(e.g., TTT)	S+,R+
'response-facilitation'	(e.g., KTK)	S-,R+
'inhibition'	(e.g., FTF)	S-,R-
'neutral'	(e.g., OTO)	S-

These conditions can then be 'tested' against the processing environments applicable in terms of the matrix shown in Figure 3.8. Facilitation effects may, for example, accrue where the 'R+' of the 'stimulus-facilitation' condition occurs in a response processing mechanism which is capable of producing facilitatory effects, but not where, as in Taylor's conclusion, a response processing mechanism is only capable of producing inhibitory effects. Given the above logic the priming effects obtainable from the nine processing environments that remain after the elimination process so far are presented again in Figure 3.9. For the purpose of ease of reference the priming conditions will only be referred to by example at this stage of the argument. The subset of exemplars (TTT, KTK, FTF, OTO) listed above are thus used in the predictions of priming effects shown in Figure 3.9.

An important point which arises from Figure 3.9 is that the OTO priming condition that was considered neutral by Taylor may not always produce a zero priming effect. On this basis the results Taylor obtained in the automatic response-facilitation condition can only be described in terms of their coincidence with the OTO condition rather than in terms of no overall priming effect. If Figure 3.9 is inspected it will be seen that only three of the nine processing environments are in keeping with Taylor's result that the resultant priming effects of OTO and KTK are the same; these are S+,R-, S±, and S±,R-. Of these S± can be discounted since it predicts no difference between the FTF condition and the OTO and KTK conditions which is clearly not in accordance with Taylor's results. Of the two remaining possibilities the S+,R- is consistent with Taylor's

Processing environment	R±	S-,R+	S-,R±
Resultant effect:			FTF
inhibition ↑	FTF	OTO FTF	OTO
zero	OTO	KTK	KTK
facilitation ↓	TTT KTK	TTT	TTT

Processing environment	S+,R-	S+,R±	S±
Resultant effect: inhibition ↑	FTF	FTF	FTF OTO KTK
zero	OTO KTK	OTO	
facilitation ↓	TTT	KTK	TTT
		TTT	

Processing environment	S±,R-	S±,R+	S±,R±
Resultant effect:	FTF		FTF
inhibition ↑	OTO KTK	OTO FTF	OTO
zero		KTK	KTK
facilitation ↓	TTT		
		TTT	TTT

FIGURE 3.9 A topological prediction of priming effects obtainable from the nine processing environments remaining in Figure 3.8. The priming conditions are those used by Taylor (1977; Experiment 3) and are shown in the form of exemplars; TTT = 'stimulus-facilitation', KTK = 'response-facilitation', FTF = 'inhibition', OTO = 'neutral'.

conclusions while the S±,R- suggests that, apart from a responding mechanism which only produces inhibitory effects, the stimulus-encoding mechanism, contrary to Taylor's conclusion, is capable of producing inhibitory as well as facilitatory effects. Further elimination from these two remaining environments is difficult on the basis of Taylor's data. If the suggested magnitude of the relative priming effects predicted in Figure 3.9 is compared with Taylor's result that the relative inhibitory effect in the FTF condition was considerably less than the relative facilitatory effect from the TTT condition then this can be considered more supportive of the S±,R- possibility. However since a comparison of the data across the three experiments suggests that the relative magnitude of the priming effects for equivalent conditions appears to vary this is indicative that the relative magnitude of effects across experiments as a measure is unreliable and so a conclusion in favour of one of the two processing environment possibilities is at best speculative.

If the question concerning the existence of inhibitory as well as facilitatory processes occurring at the encoding stage is to be pursued empirically and Taylor's (1977) paradigm is adapted for this purpose then it is necessary to have a priming condition which is neutral against which congruent and incongruent stimulus-encoding effects can be compared. In the case of the letter classification task used by Taylor (1977) the requirements for a congruent stimulus encoding condition were met by a prime and target which consisted of physically identical components while in the incongruent condition the components were different. This context demands that the prime-form for the neutral condition should thus be neither identical nor different from the target; a clearly impossible requirement. Even if a non-existent or no-prime condition is used for comparison problems may arise due to general effects such as psychological refractivity (Appendix 1) since the dimension of presence and absence of a stimulus would become salient.

The possibility of distinguishing between encoding and response effects may be considered if Taylor's (1977) paradigm is modified so that the tasks are based on a higher level of stimulus-encoding such as word-name. In this case it may be assumed that the dimension of 'congruity' can be expressed in terms of semantically or associatively related words. However a number of problems arise which would make the interpretation of any findings difficult. The associates obtainable from tables of norms such as Kucera and Francis (1967) are often in the form of the 'opposite' poles of a given conceptual dimension such as 'high-low' and these associates produce speeded responses in semantic-priming experiments (e.g., Meyer & Schvaneveldt, 1971). Accordingly the problem then becomes one of distinguishing a neutral condition from an incongruent one. That is, if a non-associate of a given target is used in an incongruent priming condition then what kind of prime can be regarded as neutral? Apart from this difficulty there is a further demand that arises from Taylor's paradigm; the arbitrary linking of certain stimuli with certain responses. With the stimulus repetitions necessarily occurring within such a paradigm it is possible that hitherto non-associates which require the same response will become associated and that this association may also result in effects occurring at the encoding stage.

It thus appears that a differentiation between both facilitatory and inhibitory effects which may occur at encoding and response stages is unlikely to be obtainable with an approach directly derived from Taylor's (1977) method. Taylor's work is, however, useful in that if processing is to be divided into encoding and responding stages then some possibilities with regard to facilitation and inhibition may have been eliminated. In particular the remaining possibilities suggest that automatic inhibitory effects are obtainable and that these may occur along with automatic facilitatory effects within mechanisms involved with stimulus-encoding. This is of contemporary interest in that it accords with the PDP models already discussed.

CROSS-ATTRIBUTE PRIMING EFFECTS

Priming studies, of which those by Posner and Snyder (1975), Taylor (1977) and Neely (1977) are representative, are important in that they have provided a direction in which issues relating to automatic and attentional processes and their loci may be investigated. These studies involving word or letter stimuli are also characterised by the effects of information presented within the same modality as that upon which a task is based. This within-attribute approach has been developed in relation to putative encoding and responding mechanisms. In Chapter 1 the relationship between the processing of verbal and nonverbal input was considered. From the models that were examined it appeared that although verbal and nonverbal information may be represented differently, encoding mechanisms were nevertheless considered to be of a similar nature. For example an analogy was made between logogens and imagens in relation to Paivio's (1978) dual-coding model, and, Nelson et al.'s (1977) single-encoding model was related to a microstructure where activation spreading among nodes could apply to both picture- and word-encoding. Furthermore with these models the results of picture- and word-encoding were assumed to commute to common responding mechanisms. On this basis some of the effects obtained in the studies involving letter or word stimuli so far discussed may also be common to priming experiments where either nonverbal or verbal and nonverbal stimuli are used. However making direct comparisons of existing work involving information in different modalities is not straightforward. One reason for this that different experimental 'traditions' appear to have evolved; for example those studying cross-attribute effects use different analytical tools to those used in the priming studies already discussed in this chapter and because of this have been concerned with a different set of questions. Although the existence of these different traditions may constitute a valid suggestion that significantly different mechanisms are responsible for priming effects according to modality it may also have the effect of masking any underlying similarities. With this in mind a comparison between within-attribute and cross-attribute experiments may be of interest insofar that it may enable the effects of any underlying mechanisms to be differentiated and, furthermore, may also suggest ways in which mechanisms responsible for both types of priming may be assimilable. On this basis some obtained contextual effects which may be regarded as cross-attribute in nature will now be examined. One example of cross-attribute priming is the well-known series of experiments using colour words and ink colours carried out by Stroop (1935).

Stroop Interference

An investigation into how the processing of object attributes may interact was carried out by Stroop (1935). Essentially he measured the time taken either to read lists of words, or, to name the colours of lists of words or shapes such as squares or swastikas. He presented lists of 100 items. On average reading a list of colour words printed in black ink took 41 seconds, when the same words were printed in different colours it took 43 seconds (the 2 seconds difference not being statistically significant). Colour-naming took longer; 63 seconds in the case of shapes and 110 seconds in the case of incongruent colour words. In summary the effect found by Stroop appears to be asymmetrical; word-naming is faster and not affected by irrelevant colours while colour-naming is a slower process which is affected by irrelevant words.

Further investigations using the Stroop paradigm have also revealed a 'semantic gradient' effect. Klein (1964) in a colour-naming task used a variety of distractor types; these included the names of the target print colours, the names of other colours, the names of objects with strong colour associations and words unrelated to colour. The Stroop effect was greatest for names of colours, intermediate for colour-object associates and lowest for words unrelated to colour.

In addition to naming tasks Stroop effects have also been investigated using comparison tasks. Within this context there are two types of comparison task; firstly 'within-attribute' where a decision is required on whether a given attribute is the same for two items (e.g., whether two word-names are the same or whether two physical colours are the same) and, secondly, 'cross-attribute' where a decision is required on whether different attributes of objects are congruent (e.g., whether a word-name correctly denotes a physical colour or vice versa). In the case of within-attribute comparisons, such as the ink colour of colour words, colour interference effects from irrelevant colour names have either been small (Morton & Chambers, 1973) or insignificant (Egeth, Blecker & Kamlet, 1969). On the other hand if cross-attribute comparisons are made, such as between the nominal identity of a colour word and the ink colour of a second object, then Stroop inhibition has been found in cases of incongruency (Treisman & Fearnley, 1969; Morton & Chambers, 1973). Both of these latter studies have also reported a 'reverse Stroop effect' where a colour word in an incongruent ink colour inhibited the matching of the name of the colour word with the colour of a row of Xs.

Although Stroop effects are usually discussed in terms of task inhibition there may also be facilitatory effects. Hintzman et al. (1972) found colour-naming of congruently coloured colour words took less time than words with no obvious colour association. Dyer (1973) used an across attribute comparison task and measured reaction times for decisions regarding the congruency of word names and ink colours for pairs of stimuli. The stimuli which had to be interrogated in terms of ink colour consisted either of a row of Xs or colour names which were either congruently or incongruently coloured. In comparison to those for the Xs, reaction times for conditions judged as 'same' (i.e., where the colour name matched the ink colour of the other item in the pair) were not only longer for incongruently coloured colour words but also shorter for congruently coloured colour words. If the effects of congruency are to be deemed facilitatory and incongruency inhibitory then assumptions have to be made regarding the nature of stimuli used in the 'neutral' conditions in the latter two studies. With this in mind it may difficult to be conclusive as the possibility that only varying degrees of inhibition or facilitation exist cannot be entirely ruled out. This point will be discussed in more detail in relation to other data.

The Stroop Effect as an Example of a General Phenomenon

The possibility has also been investigated that Stroop effects are one example of a general pattern of interference phenomena that exist between verbal and non-verbal attributes of stimuli or, more generally, between all types of stimulus attribute. Rosinski, Golinkoff and Kukish (1975) used picture-word stimuli in an experiment analogous to Stroop's. Word-naming was not found to be affected by the presence of incongruent pictures while picture-naming was found to be affected by the presence of incongruent words. Similar findings with object-naming have also been obtained by Rayner and Posnansky (1978), and Posnansky and Rayner (1977). Additionally interference effects have also been found in the naming of quantity and location (Morton, 1969; Fox, Shor & Steinman, 1971). A further interference effect occurring within a lexical-decision task has been found by Rubenstein, Lewis and Rubenstein (1971); nonwords which were homophonic with words (e.g., leef, blud) took longer to be categorised than orthographically regular nonwords that had no homophonic word counterparts (e.g., lape, dibe). The occurrence of Stroop effects in the absence of a verbal component for both target and distractor stimuli has been found in experiments involving decisions on animal pictures (Paivio, 1975), digits (Banks, Fujii & Kayra Stuart, 1976) and direction (Clark & Brownell, 1975). In summary it appears that the effect discovered by Stroop is one example of a general phenomenon where irrelevant verbal or nonverbal stimuli or stimulus attributes can influence performance on verbal or nonverbal judgements.

Accounting for the Stroop Effect

A general observation regarding Stroop experiments is that processing of task-irrelevant information appears to be automatically carried out. If this information conflicts with that required for a response then a relative delay results. A number of attempts have been made to explain the delay. One approach has been to establish a locus or loci for the delaying processes. The loci have been described in similar terms as the loci in the word or letter priming studies discussed earlier. Among the hypotheses put forward are those that suggest that loci may be cited at relatively early stages of processing, at a later 'semantic evaluation' or 'decision' stage, or alternatively, at an output or response stage. These hypotheses will now be discussed.

Early Processing

One possibility that has been suggested is that it is not possible to attend selectively to the target stimulus attribute without also attending to the non-target attribute and that one attribute interferes with the encoding of another. For example it is argued that colour-word name information interferes with the process of verbally encoding the name of an incongruent colour because the threshold of sensitivity to words semantically-related to the task attribute is lowered. This reasoning forms the basis of a 'perceptual-encoding hypothesis' put forward by Hock and Egeth (1970). One major (and perhaps obvious) problem with this hypothesis is accounting for the finding that interference is not obtained when the distracting stimulus attributes are semantically-congruent. Similarly the perceptual encoding hypothesis fails to provide an explanation of the semantic effects encountered in studies carried out by Rosinski (1977) and Lupker (1979) when words of varying semantic-relatedness to target pictures were used as distractors. A word referring to an object belonging to the same category as that depicted by a target picture (e.g., dog (word) mouse (picture)) produced a slower picture-naming response than did a word referring to a different category (e.g., car (word) mouse (picture)). The above difficulties have led to explanations of interference effects in terms other than early encoding to be sought.

Response-Competition

An explanation of the Stroop effect which has generally been regarded as more plausible than early encoding is in terms of a competition between covert responses to the relevant and irrelevant stimulus attributes; this is often expressed in the form of a 'response-competition hypothesis'. For example the verbal and physical colour attributes of a word are assumed to be processed in parallel up to a point where response processes are engaged. If both word attributes are congruent the same response programme is activated and no conflict arises. In the case of incongruency, however, the resulting covert responses may interfere and make the choice of an overt response more difficult. The degree of interference is assumed to depend upon the relative times of arrival of the relevant and irrelevant information. This may be evidenced with the effects of irrelevant words on colour naming since, as the reading of words has been found to be faster than the naming of colours (Fraisse, 1969), the verbal attribute of a word will have more time to influence output processes in comparison to the colour attribute. Additionally time may be required to suppress a response to the verbal attribute. Conversely, when considering the effects of irrelevant colours on reading, the task information is assumed to arrive at the response stage before the distractor information so that no interference is obtained. Support for the above argument has been obtained from the interference effects found in those studies where the legibility of words was reduced and the naming of colours was extensively practised in an attempt to alter the relative times required for reading and naming (e.g., Dyer & Severance, 1972; Gurmenik & Glass, 1970). Additional support for the response-competition hypothesis has been offered by Keele (1973) who found that if a key press is used, rather than a vocal response, words that do not denote colour fail to produce the small interference effect that they produce in comparison to nonwords in a naming task. In short, then, in addition to being dependent upon the relative times of arrival of relevant and irrelevant stimuli at the response stage the response-competition effect is inhibitory rather than facilitatory in nature.

Semantic-Encoding

Seymour (1977) has suggested that interference effects arise from an overlap produced as a result of the semantic-encoding of word-name and colour. Congruent information, regardless of its task relevance, assists the semantic-coding of a task relevant stimulus attribute. However if incongruent irrelevant information is also present then a further distinct semantic-code will be constructed. The resulting semantic-codes must then be distinguished in terms of their task relevance in order for any further stages of processing to proceed. It is assumed that the process of making the task relevant discrimination takes time and that this time is increased if the semantic-codes are closely related.

The evidence cited in support of this explanation is drawn from a series of experiments which attempted to separate response-related effects from semantic-encoding and decision effects. For example Seymour (1977) used the colours associated with months and seasons as a vehicle for this. In addition to finding a reliable association of spring, summer, autumn and winter to the colours green, yellow, brown and white respectively it was also found that months were also reliably allocated to seasons and that spring and autumn were regarded as opposites as were summer and winter. In a 'direct naming condition' subjects were required to name the season associated with the colour in which a season or month word was printed (e.g., responding 'spring' to 'winter' printed in green ink). In the 'opposite-naming condition' the requirement was to name the season opposite to the one associated with the colour (e.g., responding 'spring' to 'winter' printer in brown ink). Congruency of colour with a season or month word facilitated direct-naming responses. Of particular interest, however, was the finding that a word congruent with its ink colour also resulted in a faster response in the opposite-naming condition while no facilitation was obtained when the verbal components of the stimulus and response were congruent (for example the response 'winter' to yellow ink was facilitated by the word 'summer' or a summer month but not so simply by the word 'winter' or the name of a winter month). Seymour argued that if response processes were responsible for Stroop effects then a name oppositely associated to an ink colour would facilitate opposite-naming whereas if earlier stages of encoding were responsible opposite-naming would be facilitated by a congruent word and ink colour. Since the results were consistent with the latter it was argued that a conceptual encoding hypothesis was supported. A problem with the above experiment, however, is that in the opposite-naming condition subjects may have also applied the task of opposite naming to the verbal content of the stimulus. In this situation the response 'winter', for example, to the word 'summer' would be more consistent with the treatment given to nonverbal information than the response 'winter' to the word 'winter'. In view of this Seymour's conclusion may have to be treated with caution.

Another experiment carried out by Seymour (1974) required subjects to respond 'yes' or 'no' in accordance with the congruency of the position of a set of symbols in relation to the preposition 'above' or 'below' that was printed centrally in a box. In addition to the symbols being positioned either above or below the box their verbal content was varied; a row of Xs was used in a neutral condition, while other conditions used words related to the response ('yes', 'no', 'right', or 'wrong'), or, words related to the word inside the box ('up' or 'down'). A finding that was regarded as important was that a Stroop effect was only obtained with the words that were incongruously related to the preposition 'above' or 'below' rather than with response-related words. That this finding is suggestive of a cross-attribute encoding effect has, as with the previously mentioned experiment, also to be treated with caution since the strong semantic relationship between the verbal content of the two words might have prompted a response that was based according those terms rather than in terms of any conflict between verbal and spatial congruity.

Although interpretation of Seymour's experimental work is not straightforward the possibility that both facilitatory and inhibitory effects may arise as a result of semantic-encoding cannot, of course, be ruled out. So far, then, two viable loci for Stroop effects have emerged; a response stage, which may give rise to inhibitory effects dependent upon the temporal relationship between the task and distractor information, and, semantic-encoding, which, albeit advisedly, may give rise to both facilitatory and inhibitory effects.

Processing Macrostructures and Stroop Interference

Each of the above attempts to account for Stroop interference is concerned with only one out of a number of assumed processing stages or modules. Although these accounts may be valid they all suffer from a major omission; a concern with how the various elements that may comprise a processing system may interact as a whole. An attempt to repair this omission may be made by considering the encoding and responding stages that has so far been assumed but, importantly, also considering those macrostructures where the processes of picture and word-encoding have been delineated. Obvious candidates here are the 'single-encoding' and 'dual-coding' models relating to the processing of pictures and words introduced in Chapter 1. With dual-coding models picture and word information are represented differently in systems which are separate. This was compared with a common amodal semantic system in the single-encoding models. The importance of such macrostructures in accounting for Stroop interference will be first illustrated with reference to the single-encoding model proposed by Nelson et al., (1977); the sensory-semantic model of picture and word-encoding.

Single-Encoding Models and Stroop Interference

Figure 3.10 shows an adaptation of the sensory-semantic model for the purpose of analysing colour-word interference. One of the features of this model is the order in which different information attributes are encoded. The link between colour information and word information is effected through the semantic system where the concept of a particular colour is activated in order for a verbal descriptor to be attached. Thus the process of naming a colour involves both identifying the colour in

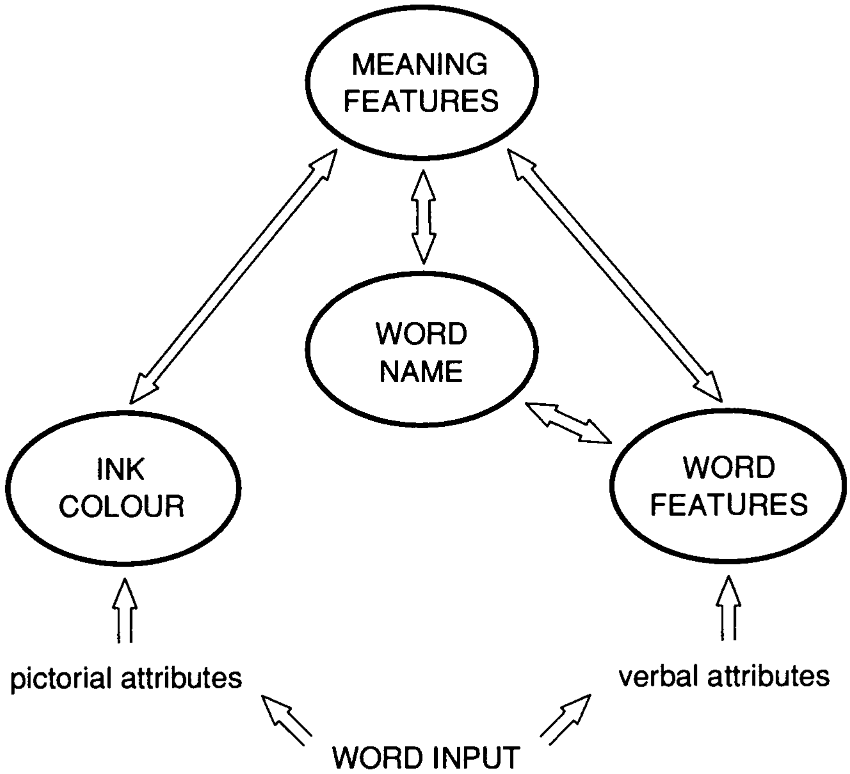


FIGURE 3.10 The sensory-semantic model of picture and word-encoding (Nelson et al., 1977) adapted for the purpose of interpreting Stroop interference effects with colour words.

terms of its physical and semantic properties before any phonemic information enabling an oral response can be accessed. Although reading a word implies an initial identification of a particular word-form a difference between this and colour-naming in the present model is that identification is already in terms of the verbal label upon which an oral response can be based. In the above structure, then, colour-naming necessarily involves semantic access whereas reading (merely word-naming) does not; the routing of information being distinctly different.

In the traditional Stroop colour-naming experiment with colour-word distractors it is likely that the first information available to the articulatory mechanisms will be the distractor since it is already in verbal form. This is also in keeping with the finding that reading is faster than colour-naming. Word-name distractor information will have to be suppressed if it is contradictory with the word-name evoked from the colour to word conversion process. Similarly if the task and distractor information is congruent output from the articulatory mechanisms may continue uninterrupted. On this basis the colour-naming response time is likely to be increased or decreased according to congruency of verbal distractor information in line with the usual Stroop findings.

In the traditional 'reverse Stroop' situation the processing demands are very different. Since the task is one of 'reading', the target input attribute is already in word-form and a process to convert from one attribute into another via a semantic link is not necessary. Task relevant information thus has a relatively direct route from input to output. In order for the distracting colour information to affect reading performance it has to start to be converted to word-form. If the time-scale required for such a conversion is reflected by colour-naming being slower than reading then any output from colour is thus unlikely to be available before the task-relevant information. Consequently the effect of distractor information in colour form upon a reading response time is likely to be minimal since a response based on the target attribute will be well underway (or effectively completed) before contrary or corroborating information arrives. This situation is also reflected within the structure of the sensory-semantic model shown in Figure 3.10 and the findings from typical reverse Stroop experiments bear this out.

The effects resulting from a structure such as that comprising the sensory-semantic model may also be considered with tasks other than reading and naming. More recently a number of experiments requiring subjects to categorise stimuli have been carried out. Smith and Magee (1980), for example, found that word-categorisation was disrupted by incongruent pictures while picture-categorisation was relatively unaffected by incongruent words; this may be seen as a reversal of the usual Stroop findings. In their experiments subjects were asked to indicate by saying ‘yes’ or ‘no’ whether or not a word or a picture belonged to a predesignated semantic category. Smith and Magee explained their results through the hypothesis that pictures access their semantic-codes more rapidly than words and that an early arrival of the distracting code was sufficient to cause an interference effect. In their study the demands on semantic processing to categorise the variety of exemplars used may be assumed to be relatively high and the explanation offered seems plausible. In terms of the structure represented by the sensory-semantic model it may be assumed that the information upon which an outputted response is based is processed in terms of the ‘meaning features’ before the phonemic codes required for the yes/no response are activated (see Figure 3.10, Page 112). Although the form of response was verbal the routing of information is different from that necessitated in the traditional word- or colour-naming paradigm.

The possible effects of response-competition and semantic-encoding discussed earlier are not necessarily incompatible with the effects that may be predicted from a structure such as implied by the sensory-semantic model of picture and word-encoding. Indeed the role of response-competition, as has just been illustrated, may be considered along with the sensory semantic structure. The important contribution that such a structure appears to offer is that it may easily account for a variety of Stroop phenomena. Furthermore it also draws attention to the idea that both the precise nature of the task and the form in which a response is effected may be important factors to be considered when interpreting cross-attribute priming effects.

Dual-Coding Models and Stroop Interference

With a dual-coding model, such as Paivio and Begg's (1981), within-attribute priming effects are predictable since the activation-level of logogens or imagens is raised by the presence of verbal or nonverbal input respectively. The existence of referential links between imagens and logogens similarly allows for cross-attribute priming. As with the sensory-semantic model such a dual-coding arrangement can also account for the differences in time required for picture naming and word reading and Figure 3.11 shows Paivio and Begg's (1981) model re-

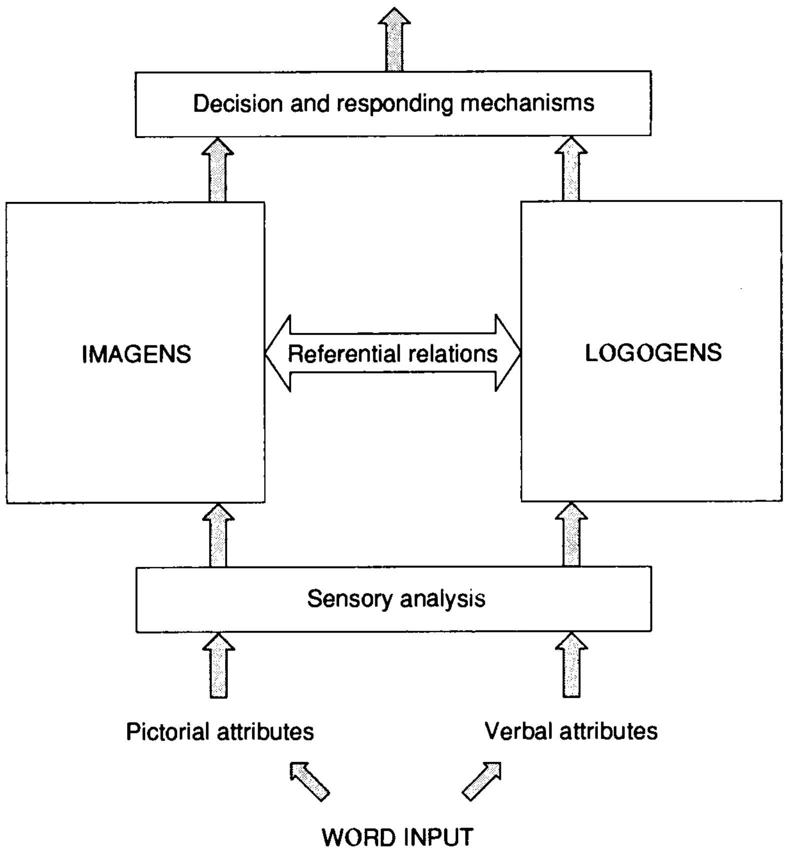


FIGURE 3.11 Paivio and Begg's (1981) model of picture and word-encoding adapted for the purpose of interpreting Stroop interference effects with colour words.

expressed for this purpose. With word-naming verbal input is routed to a logogen system from which a verbal output is directly obtainable while, with picture naming, an input has to excite its respective imagen before being communicated to a logogen from which verbal output can be derived. If the processing of ink colour in a traditional Stroop task is equated with picture processing then it might be anticipated that colour information would not be available to output mechanisms in time to influence the response to name input. By similar reasoning a reverse Stroop effect would not be expected with this dual-coding arrangement.

Smith and Magee's (1980) findings that word-categorisation was disrupted by incongruent pictures while picture categorisation was relatively unaffected by incongruent words may also be explained by a dual-coding arrangement. Their hypothesis that pictures access their semantic-codes more rapidly than words is in keeping with Paivio's (1971) view that language develops from an imaginal base and this in turn would result in the dual-coding model being image-biased. Word- and picture-categorisation tasks may be thus carried out intra-verbally or intra-imaginally and the results of the respective semantic-categorisation processes may then be outputted for a yes/no response. If the output of picture categorisation takes no longer to be communicated in yes/no terms to the verbal system than the internal communication of yes/no then Smith and Magee's findings are also consistent with the early arrival of the distracting code being sufficient to cause an interference effect.

Relative Speed of Processing Different Stimulus Attributes

The above accounts of cross-attribute priming in relation to the single- and dual-coding structures have also involved assumptions about the relative times of arrival of encoded information at responding mechanisms. A further assumption that has so far been implicit in the discussion of encoding and response-competition hypotheses is that interference effects are determined by the relative times for the different input attributes to be processed. This will now be examined more closely.

The idea that different amounts of time are required for the processing of different types of stimulus attribute and that a response to irrelevant information available prior to the response to relevant information has to be suppressed is central to both the semantic-encoding and response-competition arguments. With the traditional Stroop paradigm, for example, experiments such as those by Fraisse (1969) suggest that reading is faster than colour-naming. On this basis the asymmetry in Stroop interference effects would be due to an irrelevant word being processed faster than an irrelevant colour. This idea has been referred to as the 'relative-speed hypothesis' (Glaser & Düngelhoff, 1984) and in its strongest form is considered to be both necessary and sufficient to account for Stroop phenomena while in a weaker form it is only considered necessary.

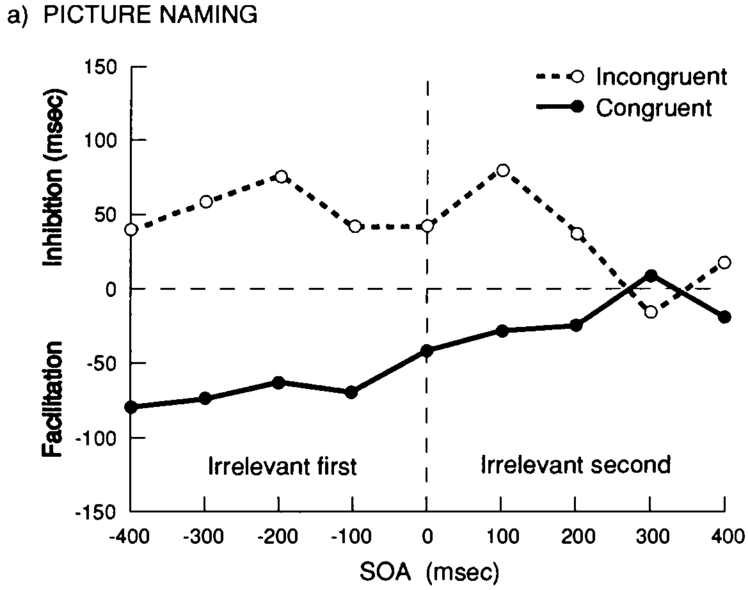
One way that the two forms of relative-speed hypothesis have been tested is through an examination of the time-course of interference effects. Investigations carried out by Neumann (1980) and Glaser and Glaser (1982) were based upon the argument that if the prior availability of distracting information is both necessary and sufficient for Stroop interference then varying the onset of the distracting stimulus attribute alone should alter the interference effect. The findings were that prior presentations of an irrelevant colour at varying time intervals up to 300 msec produced no significant effect on colour-word reading tasks and so it was argued that the strongest form of the relative speed hypothesis was not supported by those data. The weak relative-speed hypothesis was upheld, however, on the assumption that there is a greater degree of automaticity in reading than for naming (Keele, 1972; Posner & Snyder, 1975). Such an argument is also consonant with an interpretation based upon the sensory-semantic model (Figure 3.10, Page 112); although not expressed in terms of automaticity it may be argued that an effectively stronger link exists between the word-name features and phonemic features than between nonverbal visual features and phonemic features. Because a reading task in the above experimental context may be thought of as primarily one of direct conversion from graphemes to phonemes the directness of this link may explain the automaticity of the reading task. Although explanations in terms of automaticity as opposed to relative-speed may be allowable with the sensory-semantic model this may only be applicable by virtue of the nature of the reading task. At this stage there remains the possibility that a relative-speed argument in its strongest form may be tenable and verifiable given a different task type; especially one that avoids the automaticity that may prevail in grapheme to phoneme conversion. Further investigation of this issue where interference effects on different tasks have been compared has been carried out by Glaser and Düngelhoff (1984).

An argument upon which Glaser and Düngelhoff's (1984) investigation into the weak form of the relative-speed hypothesis is based may be summarised as follows: With the semantic-coding hypothesis interference arises from the accumulation of competing internal evidence for both the target and distractor and in this situation distracting effects arise from temporal proximity rather than precedence. By way of contrast, the response-competition hypothesis relates only to interference arising from the suppression of irrelevant information that arrives before the target information.

Glaser and Düngelhoff ran two picture/word interference experiments; in the first the tasks consisted of naming and reading picture and word stimuli while in the second they consisted of picture-categorisation and word-categorisation where subjects were asked to name any one of nine previously learned categories in which the word or picture exemplars were grouped. The distracting stimuli for both experiments were presented over a range of up to 400 msec before and 400 msec after the onset of the target. With the picture-naming task the prediction was that the usual Stroop interference effect should prevail throughout the range of onset asynchronies used. However with reading, in accordance with the already cited work by Neumann (1980) and Glaser and Glaser (1982), no distracting effect was expected due to a special reading automatism that overrides relative-speed effects. For the second experiment, on the basis of a strong relative-speed hypothesis, and, the apparent fact that pictures require less time to be encoded semantically in comparison to words, it was predicted that with a sufficient pre-exposure of an incongruent word distractor picture categorisation should be influenced if reading automatism presents an irregularity relevant only to interference effects with reading tasks. Glaser and Düngelhoff cited the word- and picture-categorisation experiments with simultaneously presented word and picture stimuli carried out by Smith and Magee (1980) where interference effects essentially arose only with incongruent pictures on word-categorisation, picture-categorisation remaining unaffected by incongruent words. In view of these findings Glaser and Düngelhoff also predicted that a similar pattern of results should hold with categorisation tasks regardless of the onset asynchrony between target and distractor if the relative speed explanation is merely epiphenomenal and marginal. In terms of their second experiment this meant that word-categorisation should be disrupted by incongruent pictures while picture-categorisation should be relatively unaffected by incongruent words.

The findings for Glaser and Düngelhoff's (1984) first experiment, as predicted, were similar to those of Glaser and Glaser (1982); namely that picture-naming and reading were largely unaffected by the onset asynchrony of distractors, and, that while picture-naming was affected by irrelevant words reading was not affected by irrelevant pictures (see Figures 3.12a and 3.12b). Apart from the assumed contradiction of the strong relative-speed hypothesis these findings were taken as an indication that the same processes underlie both colour/word and picture/ word interference.

Of particular interest, however, were the results of Glaser and Düngelhoff's (1984) categorisation experiment; here it was found that with picture-categorisation the inhibitory effect of distracting words only became significant when the pre-exposure time for the distractor was 300 msec or more (see Figure 3.13a, Page 121). This was weak in comparison to the effects obtained with picture-naming and with word-categorisation (see Figures 3.12a and 3.13b). A conclusion drawn from this was that the process responsible for inhibitory effects in picture-



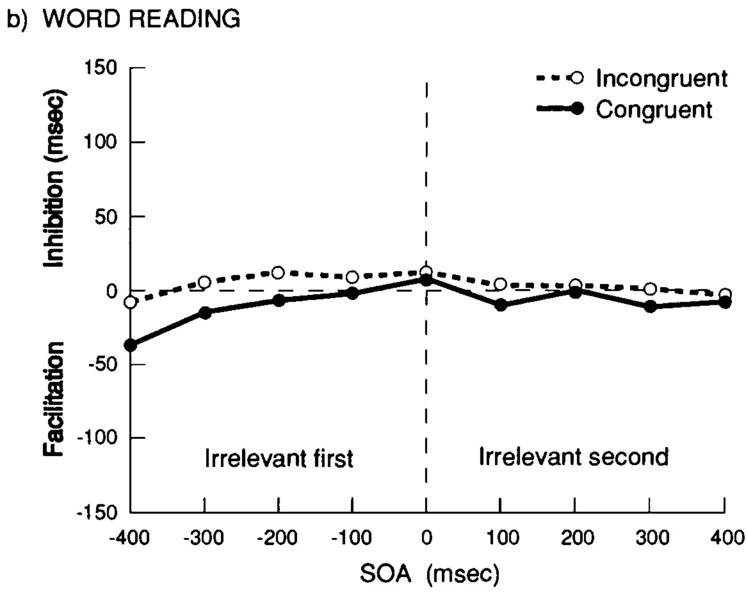


FIGURE 3.12 The variation of facilitatory and inhibitory effects with stimulus onset asynchrony obtained by Glaser and Düngelhoff (1984) according to; a) congruency of word-distractors with a picture-naming task, and; b) congruency of picture distractors with word reading.

naming and word-categorisation was unlikely to be the same as that for the picture-categorisation task. With word-categorisation strong inhibitory effects were maintained for the greater part of the onset asynchrony range, decreasing only as the post-exposure times of the distractor approached 400 msec. Since in this second experiment pre-exposed words had little effect on picture-categorisation in comparison to that of pictures on word-categorisation the temporal explanation

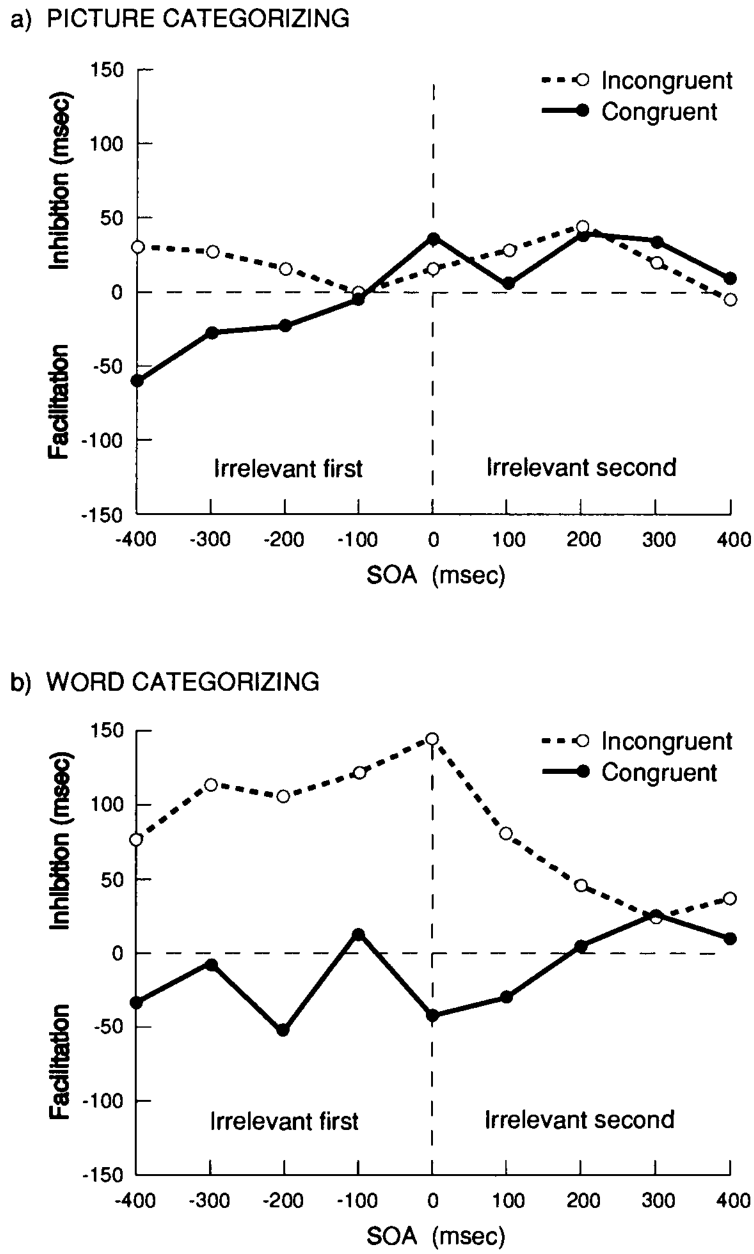


FIGURE 3.13 The variation of facilitatory and inhibitory effects with stimulus onset asynchrony obtained by Glaser and Düngelhoff (1984) according to; a) congruency of word-distractors with a picture-categorisation task, and; b) congruency of picture distractors with word-categorisation.

forming an essential component of the response-competition hypothesis was thrown into doubt. In view of the above results, then, it was considered that the strong form of relative-speed explanation was untenable while the weaker form could be supported only insofar that for interference to occur a degree of temporal proximity is required.

Because the time-course functions for reading were considered to be similar to picture-categorisation and those for picture-naming similar to word-categorisation Glaser and Düngelhoff suggested that certain similarities may also exist with regard to the internal processes connected with these pairs of activities. The similarity of the reading and picture-categorisation results may, however, be questionable, particularly when the results for pre-exposed distractors are considered. In the case of picture-categorisation, the increase in facilitation and inhibition with increasing post-exposure of the target may indeed be contrasted with the non-significant effects obtained with reading. Glaser and Düngelhoff argued that the fact that the picture categorisation effects were small in comparison to the strongest obtained with picture-naming and word-categorisation is not supportive of a relative-speed explanation and the trend may be explained either by the slow preparation of a false response or, by a similarly obtained response priming effect. In support of the explanations regarding response effects Glaser and Düngelhoff referred to Taylor's (1977) and Glaser and Glaser's (1982) work. However support from these latter studies is questionable in this respect for a number of reasons of which two follow. Firstly a response priming effect, upon whose existence Glaser and Düngelhoff's conclusions are mainly based, was only obtained by Taylor when subjects expected to actively make use of prime information; Glaser and Düngelhoff's subjects were told to ignore the primes because they were not predictive of the target. Secondly, the 'slow' facilitatory and inhibitory effects obtained by Glaser and Glaser (1982) were obtained on reading and naming tasks in experimental conditions which had but a minimal correspondence with the picture-categorisation paradigm used by Glaser and Düngelhoff.

Contrary to Glaser and Düngelhoff's conclusions it may be argued that a relative-speed account remains a possibility on the grounds that the range of pre-exposure times for the distracting stimulus was not large enough to obtain significant priming effects with the tasks that they used. An indication of this latter possibility may be gleaned from a comparison of the response times obtained across the experiments by Glaser and

Düngelhoff (1984). For picture categorisations these varied from about 730 to 810 msec while those for word-categorisations ranged between approximately 820 and 1030 msec, word-categorisations typically requiring well in excess of 100 msec time in comparison to picture categorisations. If this difference in response time is taken as an indication, albeit a very rough one (Taylor, 1977), of time differentials that may exist internally between the progress of analysed information prior to output then, on the basis of relative-speed of processing, it is conceivable that interference effects will not be detectable until the distracting stimulus precedes the target by at least 100 msec. With this in mind a trend in interference effects which only becomes statistically significant at target post-exposures in excess of 200 msec suggests that Glaser and Düngelhoff's conclusions on this matter might be reassessed in the light of results from experiments which include a greater range of target post-exposures. The above reservations of course suggest that response-competition together with relative speed of processing as an explanation for interference effects on picture-categorisation by irrelevant words cannot be ruled-out.

Since Glaser and Düngelhoff (1984) do not consider that their data are supportive of a relative-speed explanation for interference effects, questions concerning alternative explanations arise. To this end Glaser and Düngelhoff simply suggest, albeit tentatively, that the overall pattern of results is accountable through stimulus-encoding mechanisms involved in reading and picture-categorisation being immune to inhibitory effects while those for picture-naming and word-categorization remain susceptible. This suggestion, however, may be seen as little more than a re-description of the apparent data patterns rather than a more fully-fledged explanation regarding underlying mechanisms. Of interest within this context would be why early encoding might or might not be immune to interference according to both modality of input and task nature. Glaser and Düngelhoff, however, do not pursue this stimulus-encoding argument in depth.

If Glaser and Düngelhoff's suggestion that interference arising between the processing of different information attributes is a function of encoding rather than response mechanisms is to be heeded, then a closer examination of such encoding mechanisms is warranted. Since the concerns of interference studies similar to those discussed so far are not with such details of encoding an appeal must be made beyond the boundaries that characterise this area of investigation.

INTERFERENCE AND PRIMING STUDIES COMPARED

It is now of interest to consider the conclusions arising from the discussion of the Stroop-type interference studies leading up to and including Glaser and Düngelhoff's (1984) work along with the conclusions arising from the discussion leading up to Taylor's (1977) work. In the context of the interference studies characterised by cross-attribute priming (i.e., where the experimentally-controlled priming attribute is the same as that upon which the task is based) stimulus encoding was seen as being susceptible to interference arising from the accumulation of competing internal evidence such as that which may arise from a target and distractor. In this context inhibitory effects are expected and, furthermore, may be attributed to the encoding stages (e.g., Seymour, 1977). This portrait is encapsulated in the semantic-coding hypothesis.

A further account of interfering effects represented by the response-competition hypothesis is also possible in inhibitory terms. By way of contrast, in priming studies characterised by within-attribute primes (i.e., controlled priming attribute and task attribute being the same) such as those of Posner and Snyder (1975), Neely (1977), and Taylor (1977), automatic contextual effects were characterised by facilitation. One mechanism underlying facilitatory effects was assumed to be the spread of activation.

On the basis of the conclusions arrived at within the respective studies, then, a broad generalisation is that cross-attribute priming has been interpreted in terms of its giving rise to inhibitory effects while within-attribute priming has been expressed in terms of its giving rise to facilitation. This contrast is an interesting one insofar as it might be taken to suggest that fundamentally different mechanisms may underlie what are seen as differing contextual effects. In view of the implied commonalities that exist within the processing and representation of information carried in verbal and nonverbal modalities as was evident in the earlier discussion in Chapter 1 the contrast in results from the two experimental traditions seems surprising. From closer inspection of the results of these experiments, however, it has been argued that the disparities are only apparent and in some cases may only arise spuriously as a result of the task requirements.

With the above arguments in mind, a series of experiments where within- and cross-attribute priming effects could be compared more directly would be of value. If the encoding mechanisms for different stimulus modalities, which have been considered collectively in the case of interference studies have properties in common with the encoding mechanisms referred to within the priming studies then cross-modality priming effects should be similar in many respects to within-modality priming effects. Furthermore this prediction is also likely to hold in view of the assumption that similar responding mechanisms apply in both types of priming situation. If differences do exist then it may also be reasonable to predict that they are likely to be of a quantitative rather than a qualitative nature.

A further issue that arises from a comparison of the cross- attribute priming work carried out by Glaser and Düngelhoff (1984) and the within-attribute work of Taylor (1977) concerns the temporal precedence of priming stimuli. It is interesting at this point to note that the conclusion in favour of temporal precedence, or, secondary specific effect arising from work involving within-modality prime-target pairs may be put in contrast with Glaser and Düngelhoff's (1984) cross-modality picture-naming and word-categorisation results which were considered to be supportive of a temporal proximity, or, primary specific effect.

A consideration of the two broad groupings of encoding models outlined in Chapter 1 suggests that regardless of whether or not dual-coding or single-encoding systems exist they assume that verbal and nonverbal information attributes are encoded initially in functionally separate mechanisms. Interaction between these mechanisms, however, differs according to the arrangement of the overall system; in the case of a single-encoding system such as the sensory-semantic model (Nelson et al., 1977) interaction is via the common semantic system while Paivio and Begg's (1981) dual-coding model allows interaction to take place via referential links between the verbal and imageable representational systems.

With this in mind it may also be reasonable to consider these overall structures in relation to the primary and secondary specific effects postulated by Taylor (1977). In Paivio and Begg's (1981) model referential links are possible once representational codes in the verbal or nonverbal systems have been activated, in other words once the relevant logogens or imagens fire. This may be translated, for example, in terms of word-priming information having to be identified before it can influence the processing of nonverbal information. On this basis it can be argued that cross-attribute priming effects would not be expected for post-exposed primes.

Predicting the nature of the time-course of cross-attribute priming with the central semantic model may be more difficult. If encoding is considered to be continuous through time then as evidence for a given input in one modality builds-up this continuous process will be reflected in the way that information is communicated via the semantic route to encoding in another modality. On this basis a secondary effect may be expected, although the onset of this may be characterised by a gradual build-up of cross-attribute priming with time. This might contrast with a more rapid onset which may arise from logogens or imagens reaching threshold and suddenly firing as with the dual-coding model. However Taylor's (1977, Experiment 1) finding that the onset of within-attribute priming effects is represented by a sudden transient suggests that the time for the build-up of information in the encoding process is relatively short. One result of this may be that cross-attribute priming effects may also be established in a relatively short time as with Paivio and Begg's model. To reiterate, Glaser and Düngelhoff's (1984) analysis comes out in favour of an ongoing interaction among concurrently processed stimuli thereby favouring a primary specific effect with interference occurring with post- as well as pre-exposed primes. This contrasts with Taylor's (1977) conclusion in favour of temporal precedence. With this latter issue in mind a comparison which could be made more directly between the time-courses of within and cross-attribute priming effects might assist in reconciling these apparent discrepancies.

Although the distinction between stimulus-encoding effects and response-related effects may be a useful one this too has led to apparent incompatibilities; while Taylor (1977) concludes that response-competition accounts for automatic inhibitory effects, Glaser and Düngelhoff (1984) conclude that response-competition may not provide such an account. Although no inconsistencies between Taylor's conclusions and his findings were apparent, from closer inspection in relation to this issue the same can not be said with reference to the work by Glaser and Düngelhoff (1984). On this latter point the results of the time-course of cross-attribute priming effects for target post-exposures ranging beyond the 400 msec value used by Glaser and Düngelhoff would be of interest. The difficulties encountered when attempting an empirical differentiation of encoding and response effects have already been discussed with reference to Taylor's (1977) work and at present it is not obvious how this matter may be further pursued. It may be of interest, however, to examine the consistency of the results of the within and across- attribute priming experiments to be carried out in this study with the predictions that may be made from the two possible processing environments that remain after the eliminations that have been made on the basis of Taylor's (1977) data. Any predictions that are made, of course, can only be crude owing to the lack of an adequate theoretical base which encompasses the required details and to any simplifying assumptions that are necessarily incurred.

In the light of the foregoing discussion it is suggested, then, that the comparison of the results of within-attribute and cross-attribute priming experiments is of interest for the following reasons. Firstly it is argued that within-attribute and cross-attribute priming effects should be qualitatively similar in terms of time-course and magnitude. Secondly, and additionally, it is argued that the effects of temporal precedence of a prime on the processing of a related target should be detectable for both within- and cross-attribute priming. Thirdly, any priming effects obtained should be consistent with a system where response processing is subject only to inhibitory effects while encoding may be subject either only to facilitatory effects or both facilitatory and inhibitory effects.

With the above arguments in mind a major problem that arises when comparing within-attribute and cross-attribute priming effects is that the many variations that can exist even within the most basic priming paradigms can make such comparisons difficult. One reason for this is because the objects for comparison that already exist have emanated from different experimental and theoretical traditions where different types of question have been asked. There is thus a need for a series of within-attribute and cross-attribute priming experiments where the comparisons are not unnecessarily obscured and to this end such features as the task requirements, stimuli and range of prime-target onset asynchronies are kept as uniform as possible. The experiments to be described in the next chapter are carried out in an attempt to meet this need.

CHAPTER 4

CASE-PRIMING EXPERIMENTS

The experiments described in this chapter were carried out in an attempt to compare the effects of within- and cross-attribute priming where the experimental conditions were, as far as possible, equivalent. Since the results of reading and naming tasks have given rise to problems when interpreting priming effects in some of the experiments that have already been discussed another type of task is called for. In view of the pilot work described in Chapter 2 an obvious solution is a binary-categorisation task where the different to-be-identified target categories can be assigned to a signalling system such as a left- or right-hand key-press. Such a method is particularly suitable when comparing tasks based upon different word-attributes on the grounds that the complications arising from a verbalised response can be avoided.

One form of categorisation task that was found to be easily implemented involves typographic case. A priming experiment is possible where strings consisting of letters in the same physical case, upper or lower, are used to prime a binary-choice, case-decision task on similarly constructed target strings. Thus 'CHAIR-TRAIN' or 'chair-train' would represent examples of 'congruent case-priming' while 'chair-TRAIN' would be 'incongruent'. Typographic case also lends itself to cross-attribute priming if the words 'upper' and 'lower' are taken to denote the physical case-quality of letters. For example 'UPPER-WHITE' or 'upper-WHITE' would be regarded as congruent while 'UPPER-white' or 'upper-white' considered incongruent. Such cross-attribute experiments can be likened to interference experiments in the Stroop tradition where the physical case-form, which is an integral feature of a word, is considered to have a nonverbal, or, pictorial quality. Indeed if typographic case is represented mentally as an identifiable physical quality then in some ways it may be considered to have pictorial properties. This is similar to Stroop research where ink colour is often treated as a limiting case of a pictorial attribute a word, regardless of any other information that it may carry. A word can thus be thought of as a 'typographic picture' of an object. Although the analogy has already been made between the use of typographic case and the use of other forms of nonverbal information that characterise Stroop research it is at this stage worth underlining the implications this may have as far as stimulus-encoding is considered. If a word or a letter-string is encoded in terms of a typographic picture then, without going into elaborate justification, it seems plausible that both the nature and the degree of analysis involved may be regarded as being similar to that found for other attributes or objects that can be represented pictorially. To this extent, case-encoding may be treated similarly to picture-encoding when priming effects are considered.

A comparison of within- and cross-attribute priming effects with typographic case is to be sought by means of experiments of the form where a priming stimulus is presented briefly in temporal and spatial contiguity with a target stimulus upon which a speeded binary-choice-decision task is performed and registered by pressing one of two response keys. For example in such an experimental set-up a subject would observe a viewing area containing markers, between which would be presented a word or letter-string consisting of letters in the same typographic case. This initial priming stimulus would be replaced shortly afterwards (say, a few hundred milliseconds) by another word or letter-string. This second, or target stimulus, would also consist of letters drawn from one of the two typographic cases. If the letters were in upper-case then the subject would be required to press, say, a right-hand key (as opposed to a left-hand key which would be assigned to lower-case letters). The response would terminate the display, the case-decision reaction time being measured from the onset of the target. After a brief interval, say two or three seconds, another trial would begin. Such a sequence is represented in Figure 4.1. In the above situation a subject would be familiar with the general sequence of events. However the prime-target pairs would be randomised in terms of case-congruency and the target case would not be predictable. In such an experiment the subject would be informed that the effect of the primes was being investigated. This would be reasonable on the grounds that the primes would be plainly visible and subjects might form a similar conclusion anyway.

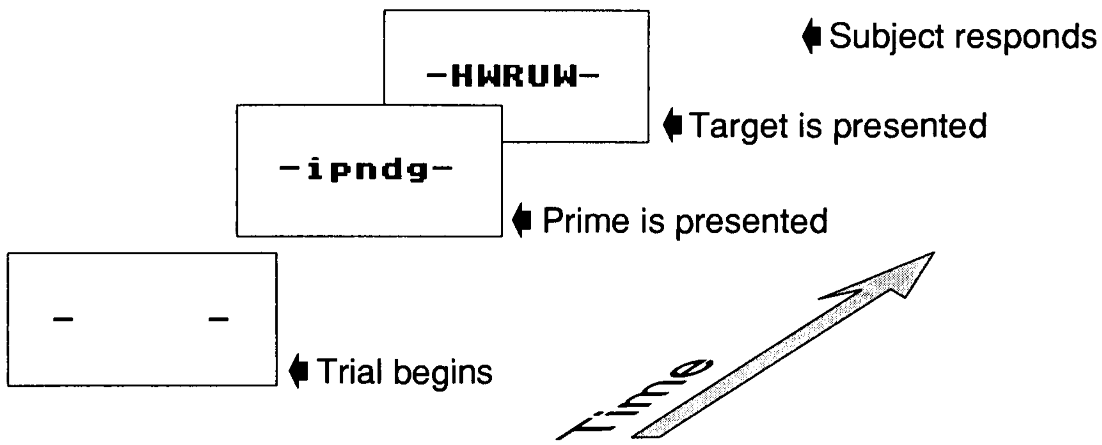


FIGURE 4.1 An example of one trial in an experiment designed to measure within-attribute priming effects. Typographic case information is used as a prime for a case-decision reaction time task.

The above experimental paradigm may be extended. If the two word-attributes to be used are the physical case-form (henceforth referred to as 'case') and the case-denoting word-name (henceforth referred to as 'name') then it follows that there are four basic priming and task relationships as shown in Table 4.1. Two of these four possibilities are of the within-attribute variety where case primes case (e.g., HJOTI-CNHEV) and name-primes name (e.g., upper-UPPER) while cross-attribute priming is represented by case priming name (e.g., BTYRG-upper) and name-priming case (e.g., upper-APWML). It may also be apparent that within- and cross-attribute priming effects may be combined. For example, 'upper-UPPER' is name-congruent and case-incongruent while 'UPPER-UPPER' is both name- and case-congruent. Such combinations will be considered in more detail later. Table 4.1 also indicates the within or cross-attribute status of each priming possibility together with location of treatment in the series of experiments to be described. In addition to congruent and incongruent priming conditions a

TABLE 4.1. Four basic possibilities for priming experiments arising from the use of typographic case information (referred to as 'case') and case-denoting word-name information (referred to as 'name') either as a controlled priming attribute, or, as an attribute upon which a choice decision task is based. ('case-case' signifies for example that case information is used to prime a case-decision task, 'name-case', that name information is used to prime a case-decision task.)

		Task-Based Attribute	
		Case	**Name**
Priming Attribute	**Case**	case-case Within-attribute (Experiment 1)	case-name Cross-attribute (Experiment 5)
	Name	name-case Cross-attribute (Experiment 3)	name-name Within-attribute (Experiment 2)

further priming condition which may be assumed to be effectively neutral is also provided. Examples of neutral priming conditions are included with examples of congruent and incongruent priming in Table 4.2 for each of the four main experimental possibilities. The effective neutrality of neutral primes may be at issue and so the choice of the given neutral primes used will be discussed within the context of each individual experiment. Since automatic priming effects are the main focus in this investigation equiprobable congruent, incongruent and neutral trials were used.

TABLE 4.2. Examples of each of the priming conditions used in the choice-decision experiments relating to typographic case. ('case-case'; case information is used to prime a case-decision task, 'name-case'; name information is used to prime a case-decision task.)

Experiment	Priming Condition	Example of Prime	Example of Target
case-case (Expt. 1)	congruent (c+)	NRWIH eihrq	YGSRO hjoti
	incongruent (c-)	hdpuw IBTUF	XBLNT rejhf
	neutral (N)	----- -----	FPAWR lpevo
name-name (Expt. 2)	congruent (n+)	upper lower	UPPER LOWER
	incongruent (n-)	lower upper	UPPER LOWER
	neutral (N)	----- -----	UPPER LOWER
name-case (Expt. 3)	congruent (n+)	upper lower	FDIKR igtpo
	incongruent (n-)	lower upper	TLRPA cnrll
	neutral (N)	ether ether	ONTRW galrn
case-name (Expt. 5)	congruent (c+)	HSRWE mbmpr	upper lower
	incongruent (c-)	jmwds WPTYU	upper lower
	neutral (N)	----- -----	upper lower

GENERAL DESIGN CONSIDERATIONS

Some of the broader issues relevant to the performance of primed decision tasks have already been discussed and the present concern is to consider those issues that are specific to the effects of case- or name-primes in a case- or name-decision task.

Individual Letters or Letter Strings

Although words or letter-strings for both primes and targets have been used to illustrate the above case- and name-priming possibilities the choice between words or strings consisting of several letters rather than individual letters has yet to be considered. A question that immediately arises concerns the extent to which each of the typographic cases is identifiable so that case can in principle be used as an effective priming attribute. It is possible that typographic case can be perceived in terms of general graphemic qualities. Thus the existence of such general features as ascenders or descenders and contour provides a graphemic quality which may allow identification of each of the two typographic cases to be independent of letter or word context. Since some letters (such as ‘c’ or ‘k’) when presented individually have a degree of ambiguity with respect to their case the use of strings consisting of a variety of letters all either in upper- or lower-case is likely on balance to reduce such ambiguities on account of some case-typifying features being more identifiable in the context of a group of letters. For example the string ‘ckwps’ may be more readily classified as lower-case then any one of its elements would be if presented individually.

Distinguishing Between Prime and Target Stimuli

Performance on a primed case-decision task requires not only the ability to categorise incoming stimuli in terms of typographic case but also the ability to identify which stimulus from a given spatial and temporal array is the target and then to respond appropriately. If the prime and target stimuli are displayed over the same area and at the same position then distinguishing between the prime and target may not be easy, especially in congruent priming conditions (e.g., NUERL-RVFKI) where prime and target may be identical or similar in form. With this in mind and with a further view to allowing the use of identical primes and targets the prime and target positions were spatially offset, even though any priming effects may possibly be reduced owing to influence of an 'input selection' effect dependent upon spatial location (Triesman, 1969).

The Time-Course of Priming Effects

The time-course of any priming effects obtained in cross-attribute experiments (see Table 4.1) is of interest in view of the issues that have arisen with regard to the possibility of the relative-speed account offered by Glaser and Düngelhoff (1984) for priming (or interference) effects. In particular, from the discussion of Glaser and Düngelhoff's (1984) work in the last chapter it was indicated that the range of target post-exposures should be well in excess of the difference in times required for word- and picture-categorisation tasks, that is, at least 200 msec. In view of this and also with the possibility in mind that the time difference in case- and name-decision is likely to be of a similar order of magnitude to that for Glaser and Düngelhoff's categorisation tasks it was decided to present primes up to 480 msec before and up to 480 msec after their respective targets. Added together, then, the total range of prime pre- and post-exposures was 960 msec.

In addition to deciding the range of SOA values to be used there is a further consideration with regard to the required resolution of the time-course. Although measurements taken at small increments in SOA over a wide SOA range may be useful this, of course, has to be balanced against the inevitable demands that this would entail upon subjects' time and concentration, since large numbers of trials are necessary for testing each priming situation. A compromise has been reached for the present series of experiments where relatively smaller intervals in SOA are used as the positive and negative SOAs approach zero. This is because issues concerning the relative speed of processing different stimulus attributes are of interest in the present study and since the effects arising from relative speeds are likely to be detectable at shorter SOAs. With this in mind and also with regard to the available instrumentation the SOAs used were -480, -320, -240, -160, -80, -40, 0, 40, 80, 160, 240, 320, and 480 msec, where the minus sign indicates target preceding prime.

Choice of Subjects

The research strategy has been to carry out the main experimental work required for developing the argument on a 'self case study' basis. There were two reasons for this. The first is practical in that the arduous regime could not have engaged a disinterested subject for the needed length of time. The second reason is epistemological, in that the investigator wished to have the maximum possibility of tuning design modification in step with the research as being monitored from the dual perspective of experimenter and subject. However, whenever an apparently stable key phenomenon emerged in this process it was then retested in some form on ten or more additional subjects. Only if confirmed would the feature be allowed a place in the developing model. For reasons of continuity across experiments and readability the data quoted in the main text relate to the investigator as subject. If these data differ substantially from additional-subject data then this is discussed as appropriate; any references to additional-subject data being made explicit. Although full details of the results obtained with additional subjects are contained within Appendix 3 a convention nevertheless adopted is to present a reduced-size copy of the graphical representation of additional-subject data as a footnote on the same page below the graphical representation for the corresponding main-subject data. Experimental procedures are reported in third-party form. However, apart from the administration of instructions, the procedures followed by the investigator as subject were identical to those followed by the additional subjects.

Bias and Practice Effects

Choice reaction time experiments generally require a large number of trials for priming effects to be detectable. In order to investigate the time-course of priming effects an even larger number of trials is required for any one subject. In view of this the effects that may arise from overfamiliarity with an experimental situation will be briefly considered. Apart from an expected overall reduction in response latencies in keeping with other reaction time results, extensive practice may lead to bias resulting from subject-generated hypotheses arising from perceived patterns of events occurring across experimental trials.

A guessing bias as to the nature of the target might be additionally imposed. For such a bias to have a condition-dependent effect, however, either the prime-types would have to be predictive of priming conditions, or, the occurrence of the priming conditions themselves would have to be predictable. The possibility of the latter can be minimised by the use of a different random sequence of trials for each experimental run while the possibility of bias arising simply from prime-type, rather than priming condition, can be minimised by ensuring that a given prime-type is used equally across priming conditions. The use of a computer to generate and present stimuli randomly prevents the investigator along with other subjects from having prior knowledge of the order of trials.

EXPERIMENT 1: Case-Priming of Case-Decision

In this first experiment the aim is to look for any effects of case-priming upon a speeded case-decision task. In addition to establishing whether or not case-priming effects are obtainable the results of this experiment will provide a baseline against which the results from the other priming experiments can be compared.

This experiment, in line with the experiments that are to follow, attempts to provide what are termed congruent, incongruent and neutral priming conditions. A 'case-congruent' condition is where both the prime and target letter strings are in the same case, and a 'case-incongruent' condition is where the prime string is in a different case to that of the target. Examples of these conditions are shown in Table 4.3. In order to ascertain whether priming is facilitatory or inhibitory in nature it is

TABLE 4.3. Examples of the three priming conditions used in Experiment 1.

Condition	(Notation)	Example of Prime	Example of Target
case-congruent	(c+)	NRWIH	YGSRO
case-congruent	(c+)	eihrq	hjoti
case-incongruent	(c-)	hdpuw	XBLNT
case-incongruent	(c-)	IBTUF	rejhf
neutral	(N)	-----	FPAWR
neutral	(N)	-----	lpevo

necessary to have a neutral priming condition for comparison. The difficulties of devising 'neutral' priming conditions have already been discussed (see Chapter 3) and in this experiment the prime consisted of a string of minus signs, chosen because they were judged to be least biased to either of the typographic cases. This is referred to as the 'neutral' condition (also shown in Table 4.3).

PREDICTED PRIMING EFFECTS

From the discussions in the earlier chapters two important likely sources of influence upon a case-primed-case-decision task have emerged; encoding processes and response processes. These processes will be examined in turn. Since the response times that are measured experimentally may be considered to be a resultant of encoding and response effects a way in which such a resultant can be predicted will also be included.

Encoding Effects

While it has been argued that response processes may only account for inhibitory effects (Chapter 3) the encoding models so far considered may be put into two groups; those that account only for facilitatory effects and those that account both for facilitatory and inhibitory effects. If typographic case is an attribute that is capable of sustaining priming effects then predictions occurring as a result of encoding processes may be in accord with those traditionally made with regard to prime target congruency and as such may be considered to be relatively unproblematic. Such predictions are shown in Figure 4.2. Table 4.3 (Page 138) may be consulted for notation and examples.

Since response latencies cannot be determined precisely, the predictions are essentially ordinal rather than interval. However some assumptions regarding the magnitude of priming effects are implied and are expressed in terms of the arbitrary units of scaling shown. In the facilitatory and inhibitory model the degree of inhibition obtained with incongruent priming at the encoding stage is assumed for present purposes to be of a similar order of magnitude as the degree of facilitation obtained with congruent priming.

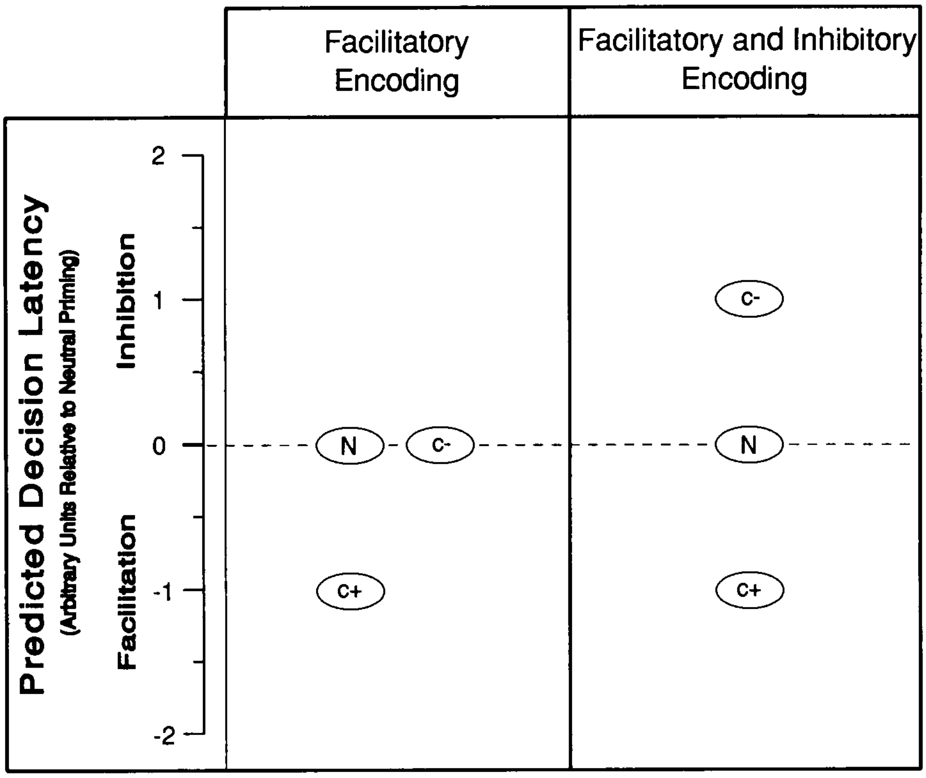


FIGURE 4.2. A schematic representation of the relative effects of encoding processes upon case-decision latencies according to priming condition. ('c+' = case-congruent priming, 'c-' = case-incongruent priming, N = neutral priming.)

Responding Effects

From the discussion in Chapter 3 it is here assumed that response mechanisms may account for inhibitory effects arising from incongruent primes (c-) while for congruent priming (c+) they will have no effect. The magnitude of inhibition obtainable with incongruent priming at the responding stage is considered to be similar to the magnitude of any effects that might occur due to encoding. While there are no theoretical grounds to support this latter assumption some guidance may be taken from Taylor's (1977, Expt. 3) findings. Figure 4.3 summarises the effects predicted on this basis.

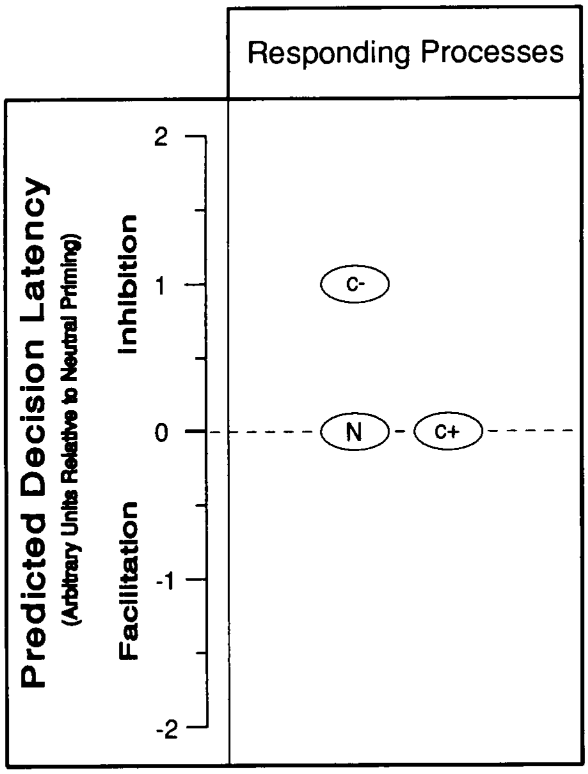


FIGURE 4.3. A schematic representation of the relative effects of responding processes upon case-decision latencies according to priming condition. ('c+' = case-congruent priming, 'c-' = case-incongruent priming, N = neutral priming.)

Resultant Effects

For the present, predictions of the combined effects of encoding and responding processes will be based upon the model used by Taylor (1977). In this model it is assumed that the processes occur both independently and serially. The possibility remains, however, that encoding and responding processes may interact so that prediction of combined effects becomes difficult. In answer to this it may be argued that since the two groupings of mechanisms differ significantly in function as well as in terms of the peripheral mechanisms with which they may commute, assumptions such as those used by Taylor are not unreasonable as a starting point. On this basis additive rules can be used. Of particular interest is the response latency for the incongruent (c-) condition in relation to the two encoding models discussed. Where the encoding stage is characterised only by facilitatory processes inhibition from an incongruent case-prime is only obtained at the responding stage. By way of contrast when encoding is characterised by both facilitatory and inhibitory processes a measure of inhibition is obtained both at the encoding stage as well as at the responding stage. If the inhibitory effects at the encoding and responding stages are assumed to be additive then the final response latency would be expected to be correspondingly greater than with encoding processes which are only facilitatory.

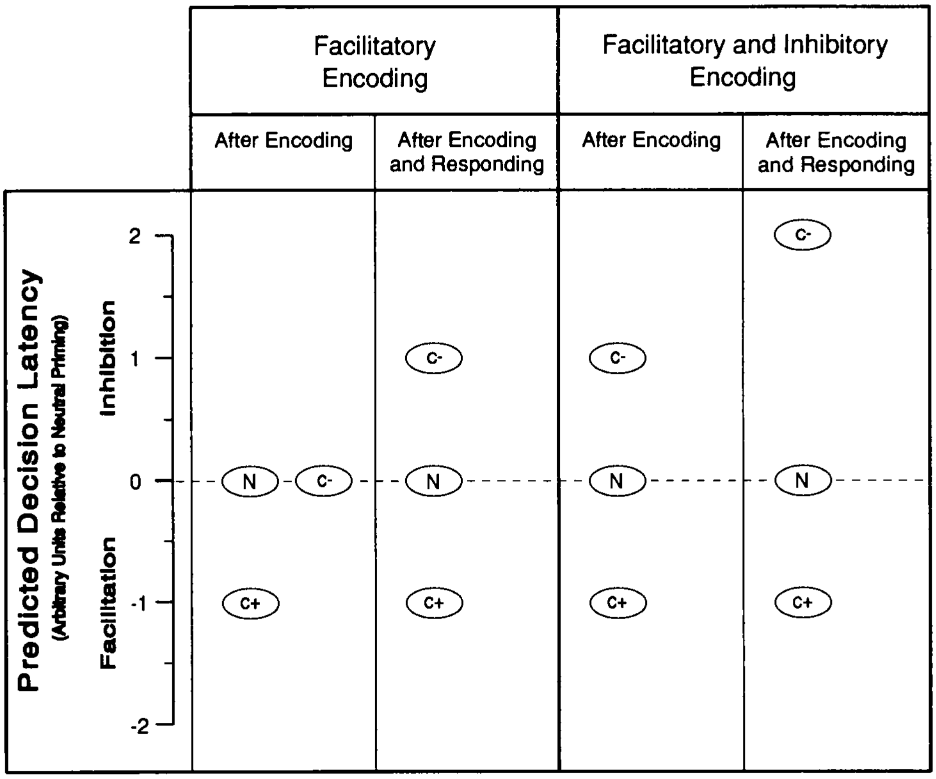


FIGURE 4.4. A schematic representation of the relative resultant effects of encoding and responding processes upon case-decision latencies according to priming condition. ('c+' = case-congruent priming, 'c-' = case-incongruent priming, N = neutral priming.)

Figure 4.4 summarises the resultant priming effects arising from both encoding and responding processes for the models presently considered; essentially from adding Figures 4.2 and 4.3. For ease of reference the information contained in Figure 4.2 is repeated in the 'after encoding' columns of Figure 4.4 so that the derivation of the resultant predicted effects may be more easily assessed.

Inspection of Figure 4.4 suggests that support for the existence of either the 'facilitation-only' or the 'facilitation and inhibition' processing model may be obtained from the relative magnitudes of facilitatory and inhibitory effects obtainable experimentally. However a note of caution is necessary as it may only require relatively minor variations in magnitude in the predicted effects occurring at each stage for the resultant priming profile ('Encoding plus responding' columns in Figure 4.4) to be the same in the case of either model. With this in mind a comparison of the relative magnitudes of facilitatory and inhibitory effects obtained from this experiment alone does not provide reliable support in favour of one or other of the encoding models.

Predicted Time-Course of Encoding and Responding Effects

If Taylor's (1977) notion of 'specific effects' is considered in relation to the encoding stages, then in the present within-attribute experiment two basic types of time-course are possible. Firstly, in the case of primary specific effects the ongoing interaction that may occur between prime and target information would result in priming effects being detectable at both positive and negative SOAs. This is in accord with the principle of temporal contiguity expressed by Glaser and Düngelhoff (1984). With secondary specific effects the necessity of temporal precedence would suggest that priming effects would only be obtainable for positive SOAs. With this in mind it would be expected that while priming effects might not be obtainable at an SOA of zero, there might be sufficient initial processing of prime information for any facilitatory or inhibitory processes to take effect. This would be within, say, a few tens of milliseconds or, at least, by the shortest SOA of 40 msec used in the present experiment. If inhibitory effects are also obtainable at the encoding stages then these should follow a similar time-course as any facilitatory effects. This latter prediction is based upon the earlier proposal derived from PDP accounts that inhibitory mechanisms are of a similar but complementary nature to facilitatory ones.

If a response-competition account is used as a basis for predicting the time-course of inhibitory effects occurring at the responding stage then interference effects should not be obtained if incongruent prime information arrives after the target. With simultaneous or previously presented distracting information covert responses should interfere and inhibition should result. It thus follows that differences in response latencies between neutral and incongruent priming conditions should only be obtained for SOAs of zero or above.

Other Factors that may affect Response Latencies

Apart from the already discussed priming effects in relation to encoding and response-competition other factors may result in selective effects being derived from general effects. For example general effects in the region of the shorter SOAs (less than 200 msec, say) may arise as a result of the temporal resolution of various peripheral and mental processing elements that may be involved (cf., Turvey, 1973). The resulting phenomenal effect of successive stimuli may be in the form of a detectable flicker. Such a flicker may not only signal target arrival but also have the effect of increasing the level of phasic alertness (see Appendix 2) which may lead to a speeded response. Conversely, a detectable flicker may distract or lead to a psychological refractory effect (again see Appendix 1) and a delay also becomes a possibility. Although the effects of phasic alertness and refractivity are essentially general they may also have condition-dependent repercussions. For the present, this possibility of indirect condition-dependent effects is merely noted with a view to a more detailed discussion in the results later on.

Summary

From the discussion so far it appears that the effect of a prime containing typographic case information on case-decision may vary according to both the prime-target case-congruency and onset asynchrony. The principal factors identified as responsible for congruency-dependent priming effects are encoding and responding mechanisms. However it is also provisionally suggested that more general factors such as phasic alertness and psychological refractivity may also indirectly lead to congruency-dependent effects. While the predictions relating to the magnitude of effects arising from encoding and responding mechanisms are highly speculative they may be considered along with other evidence in relation to the time-course of effects in order to indicate the role of underlying mechanisms in priming. In this first experiment the distinction between primary and secondary specific effects has been considered in relation to predictions concerning the time-course of effects. Additionally the effect of 'facilitation-only' and 'facilitation and inhibition' models of encoding have been considered along with the effect of responding mechanisms to make further predictions regarding the time-course and magnitude of congruency-dependent effects. The above predictions are now tested.

METHOD

Apparatus and Stimuli

An Acorn A310 microcomputer and video monitor were used to present stimuli and time the responses. Responses were indicated by pressing one of two conveniently sited keys at either end of the computer keyboard with the forefinger of either hand. The monitor employed conventional raster scanning with a recycling time of 40 msec and thus the minimum increment in stimulus duration and onset asynchrony was limited to this amount. Apart from a centrally positioned 7 x 3 cm rectangular aperture the monitor screen was masked with grey card. Stimuli consisted of strings of five random letters or a row of five horizontal bars (the minus sign used in arithmetical notation) which were the same width as most of the letters. Within each string all the letters were entirely in upper or entirely in lower-case. The letters were in white on a dark ground and each formed within a 5 x 9 matrix. Each completed string occupied an area which measured approximately 30 mm horizontally by 6 mm vertically. In order to aid both fixation and target identification two arithmetic minus signs arranged horizontally and about 45 mm apart acted as markers. All target stimuli were located centrally between the markers while all primes were presented one centimetre below the targets as shown in Figure 4.5. The viewing distance was approximately 50 cm.

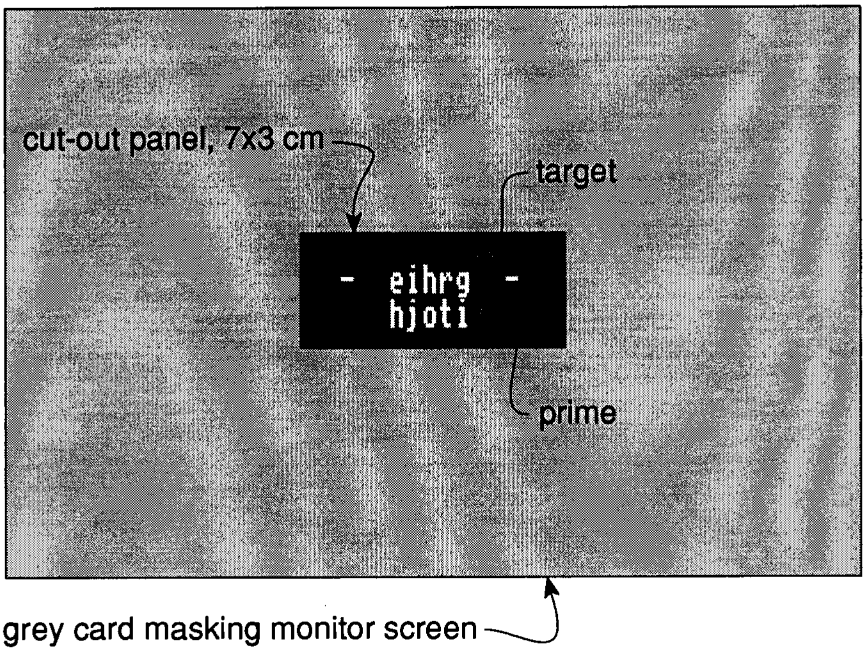


FIGURE 4.5. An example of a prime and target display used in Experiment 1 showing the spatial arrangement in relation to two line markers.

Pairs from a set of stimulus items was used for each trial, one item as a prime and the other as a target. The stimuli were arranged according to the three experimental conditions shown in Table 4.2 (Page 133). The conditions were sequenced quasi-randomly so that there was no excessive clustering of any one experimental condition. Experimental trials were in blocks of 72 and similarly-created practice trials were in blocks of 24.

Procedure

General instructions were given about the task and it was stated that reaction times were being recorded. The purpose of the experiment was disclosed insofar that it was said that the effect of the presence of one letter-string upon the response time to another was being investigated. Subjects were informed that a target string of letters would appear level with the markers and were asked to respond to this as quickly and as accurately as possible by pressing one of two keys situated beneath the index finger of each hand; right for upper-case strings and left for lower-case strings. Subjects were also informed that another string of letters or characters to which no response was required would appear just below the target. Figures 4.6a to 4.6c show the sequences for each trial; these vary according to the temporal order of the prime and target. For positive SOA values (pre-exposed primes) trials began with a priming stimulus which remained visible throughout the duration of the onset asynchrony set for the experimental block. A target stimulus was then presented which, along with the prime, remained visible until the subject responded. As there was no dark interval between the prime and target for pre-exposed primes the prime-target stimulus onset asynchrony was also equal to the duration of the prime. For negative SOAs (post-exposed primes) each trial began with a target stimulus which remained visible until the subject responded. For each of these trials a prime was also destined to be exposed at a point in time after the beginning of the trial that was equal to the SOA duration set. If the subject's response time was less than the predetermined SOA duration then the prime would not be presented. If the subject's response time was greater than the SOA duration then the prime would be presented and remain visible along with the target until the subject responded. For SOAs of zero the prime and target were presented simultaneously, both remaining visible until terminated by the subject's response. Reaction times for all trials (measured from the onset of the target) were recorded by the computer and only those response times falling within a 200 to 1000 msec range were accepted for analysis. A dark interval of 1500 msec elapsed between successive trials.

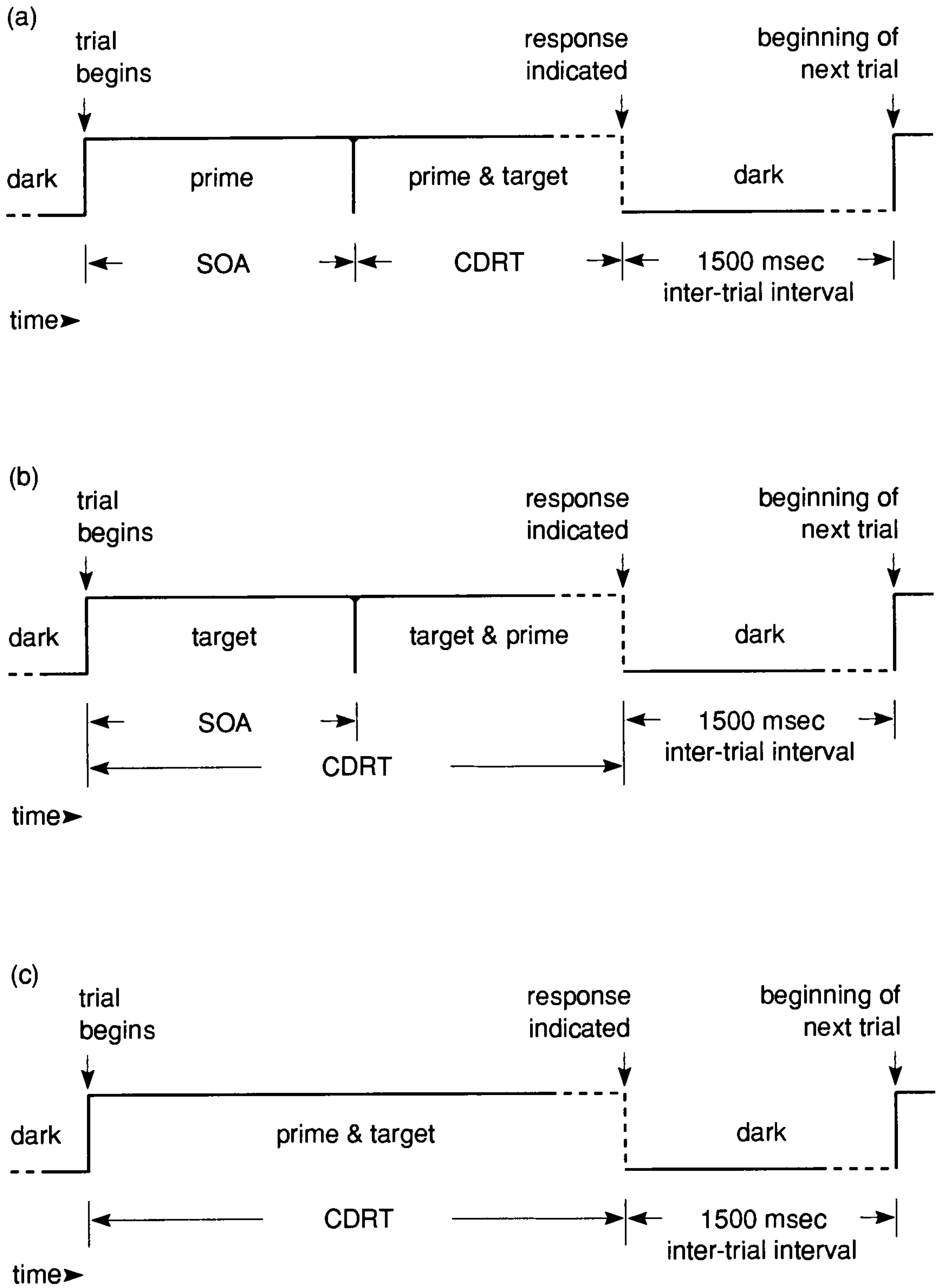


FIGURE 4.6. Schematic representation of the sequence comprising a single trial for Experiment 1: a, for positive SOA values; b, for negative SOA values; and c, for zero SOAs. (CDRT = case-decision reaction time.)

Each session began with the block of 24 practice trials, the SOA being set at a value equal to that used in the first experimental block. If necessary further blocks of practice trials were run until a balance between speed and accuracy was attained; the criterion being at least 80% accuracy for mean response times of 700 msec or less. SOAs of -480, -320, -240, -160, -80, -40, 0, 40, 80, 160, 240, 320, and 480 msec were used in the experiment. The SOA was held constant within each block of trials but was altered randomly between blocks, each SOA value being used for two blocks. Each block of experimental trials lasted approximately five minutes and was separated by a rest period of approximately three minutes; in total a session of nearly two hours. At the end of the session the subject was asked (in the form of a leading question) to say whether the horizontal bars which were occasionally visible were more similar to upper-case or lower-case letters and the response was noted. Experimental sessions were repeated so that a total of twelve sets of results were obtained.

RESULTS

Out of a total of 11,232 case-decision responses 15 fell beyond the allotted 200 to 1000 msec interval. Three of the 15 outlying responses were shorter than 200 msec and due to false starts while those above 1000 msec were due to factors such as insufficient pressure on a response key or minor lapses in attention. The 15 outliers were not considered in any further analyses including the compilation of error scores.

Response Latencies

Latencies for correct responses were subjected to a 13 (SOA) by 3 (Congruency) ANOVA. Case-priming effects were obtained; the variation of mean response time with stimulus congruency was significant, $F(2,10063) = 38.41$, $p<.001$, as was the main effect for SOA, $F(12,10063) = 31.75$, $p<.001$. A significant interaction between SOA and Congruency was also obtained, $F(24,10063) = 4.02$, $p<.001$.

The above data were further examined in terms of prime-target order. An SOA by Congruency ANOVA indicated significant case-priming effects for pre-exposed primes, that is, for the SOA range 40 to 480 msec $F(2,4683) = 82.10$, $p<.001$. No significant case-priming effects were obtained for post-exposed primes (SOA range -480 to -40 msec), $F(2,4622) = 0.02$, $p>.001$. Interaction between SOA and congruency was both non-significant for pre-exposed primes $F(10,4683) = 1.61$, $p>.001$, and non-significant $F(10,4622) = 0.24$, $p>.001$ in the case of post-exposure. The main effect for SOA for both pre- and post-exposed primes was significant, $F(5,4683) = 17.67$, $p<.001$ and $F(5,4622) = 33.14$, $p<.001$ respectively.

The variation in the magnitude of case-priming for different SOAs was further examined by calculating the mean correct response times for each of the SOA-levels for each priming condition. These means are represented in Figure 4.7 as a time-course. The means for the case-congruent and case-incongruent priming conditions were also subtracted from the means for the neutral condition so that difference scores were obtained. These differences are shown in Figure 4.8; as is conventional, the term 'inhibition' refers to positive differences from neutral values while 'facilitation' refers to negative differences. A further convention adopted is one where the stimulus onset asynchrony (SOA) of the prime and target is measured in relation to the onset of the target so that prime pre-exposures are shown by positive SOA values while prime post-exposures are shown by negative SOAs.

The time-course plots in Figures 4.7 and 4.8 display a visual consistency which may be seen as supportive of the reliability of the obtained effects. This reliability was largely confirmed by a series of one-way ANOVAs carried out across congruency conditions for each SOA. When a significant ($p<.05$) congruency effect was obtained for a given SOA, multiple comparisons of response time means were made using the Newman-Keuls method. The test statistic derived from this method is represented by the letter 'Q'. The results of these tests will be reported only when the significance or non-significance of an effect is germane to the argument and may not be obvious from the above representations. A significance criterion of p<.05 is used for the results quoted in the remainder of this section.

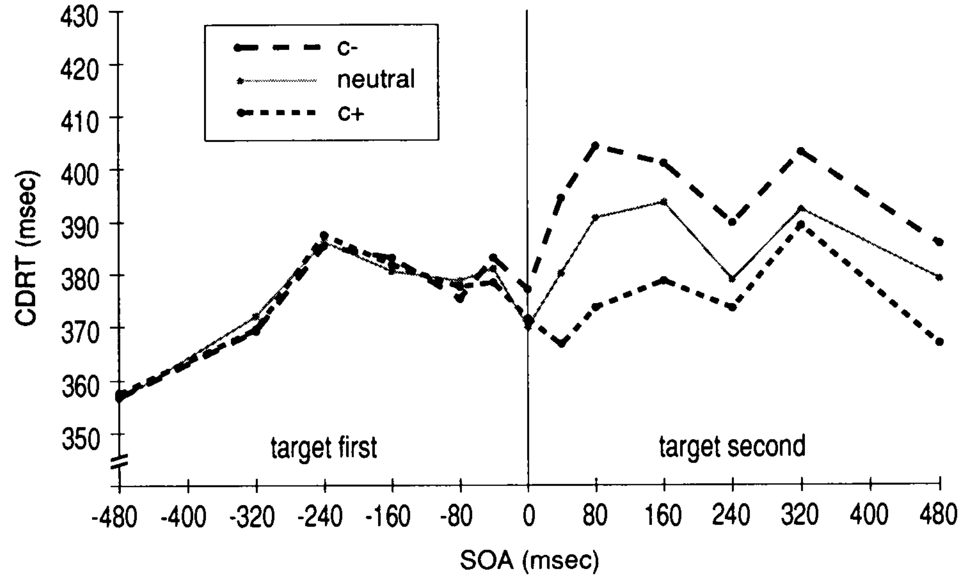


FIGURE 4.7. RESPONSE TIMES: Mean response times for correct case-decisions as a function of priming condition and prime-target stimulus onset asynchrony for Experiment 1. Each mean is based on 288 trials for one subject. (Results for ten additional subjects obtained over the SOA-range -160 to +240 msec are shown in Figure A4.7 below.)

From Figures 4.7 and 4.8 it is clear that no significant differences were found between the CDRTs obtained for any of the three priming conditions over the SOA range -480 to -40 msec. Although some variance in CDRT at zero SOA might be inferred from inspecting the main-subject data in Figure 4.8 this was found to be non-significant, $F(2,758)=1.69$, $p>.05$. The situation was different, however, throughout the range 40 to 480 msec where CDRTs were found to be modulated according to priming condition; congruent primes produced the shortest

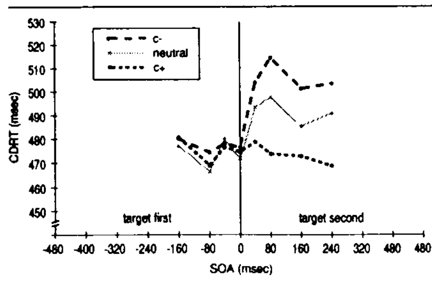


FIGURE A4.7. RESPONSE TIMES: As for Figure 4.7; mean correct case-decision response times for ten additional subjects over the SOA-range -160 to +240 msec. Each mean is based on 288 trials. (See Appendix 3 for further details.)

response times while incongruent primes produced the longest. For positive SOAs a difference in response times for incongruently-primed targets in relation to the neutral condition was well-established by

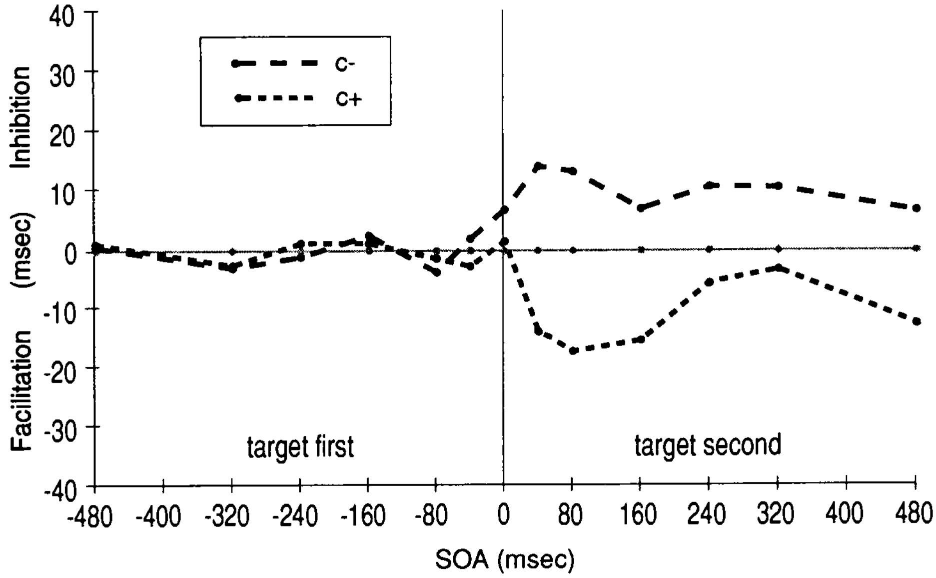


FIGURE 4.8. RESPONSE TIMES: The difference in mean response times for congruent and incongruent priming in relation to neutral priming for correct case-decisions as a function of prime-target stimulus onset asynchrony for Experiment 1. (Results for ten additional subjects obtained over the SOA-range -160 to +240 msec are shown in Figure A4.8 below.)

40 msec SOA, Q,763=4.88, p<.05. This difference averaged 10.4 msec across the 40 to 320 msec SOA range. However significant case-incongruent effects were not obtained at SOAs of 160 and 480 msec; Q,780=2.50, p>.05 and Q,797=2.32, p>.05 respectively. The difference in response-times for congruently-primed targets in relation to the neutral condition averaged 11.1 msec but varied markedly according to SOA; a maximum of 17.0 msec, Q,746=5.91, p<.05 was reached at 80 msec SOA while the differences of 5.5 msec at 240 msec SOA, and 3.1 msec at 320 msec SOA were not significant; Q,793=1.92, p>.05 and

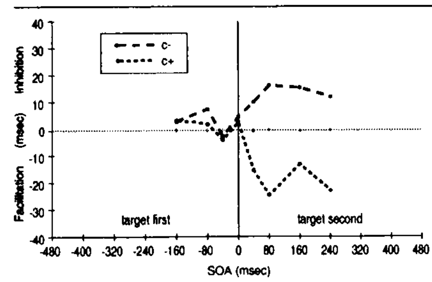


FIGURE A4.8. RESPONSE TIMES: As for Figure 4.8; The difference in mean response times in relation to neutral priming for ten additional subjects over the SOA-range -160 to +240 msec. (See Appendix 3 for further details.)

Q,804=1.00, p>.05 respectively. The variations in the relative differences in priming effects for the positive SOA range shown in Figure 4.8 is consistent with the significant SOA by congruency interaction reported earlier.

Although this opening experiment was designed to investigate the variation of the priming effect between congruency conditions at different SOAs rather than the variation of response time with SOA some observations regarding this more general response time variation may nevertheless be made. Since separate blocks of trials for all SOAs were run consecutively in randomly varied sequences it may be reasonable to assume that over the twelve experimental sessions any systematic variation with SOA of carry-over effects resulting from such factors as practice or fatigue would be minimal. An inspection of Figure 4.7 suggests that the minimum disruptive effect on response latency was obtained at prime post-exposures of 480 msec. A subjective observation that was made in the course of the experimental trials was that very few primes were visible at the longest negative SOA value. This, of course, may be explained by trial-terminating responses being made before the occurrence of a prime. The observation is backed-up statistically; at the longest prime post-exposure of 480 msec the mean response time across priming conditions was 356.6 msec, SD=46.3. Although no clear trend in overall response latencies for the remainder of the SOA range is apparent it may be noted that local maxima occur at SOAs of -240, 80, and 320 msec.

Error Rates

The error rates for the three priming conditions are expressed in Figure 4.9 as proportions of the total responses for each condition at each SOA-level. As with response latencies the differences in error rates for the congruent- and incongruent-priming conditions in comparison to the neutral condition were also computed and these are shown in Figure 4.10. The statistical significance of the effects suggested by Figures 4.9 and 4.10 was largely corroborated by a series of chi-square tests, the results of which, again, are reported only when the significance or non-significance is germane to the argument and may not be obvious from the figure.

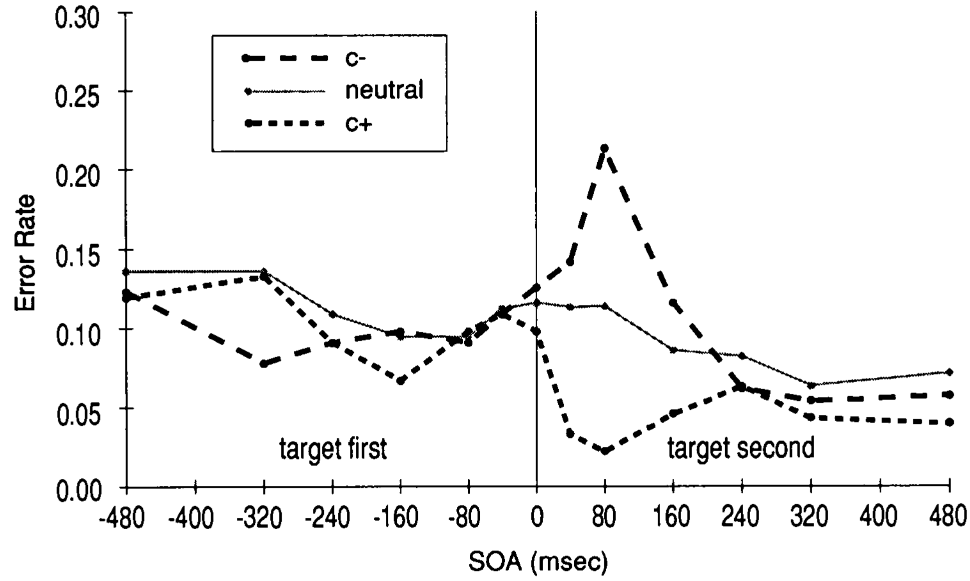


FIGURE 4.9. ERRORS: The variation in error rate according to priming condition and stimulus onset asynchrony for Experiment 1. Each mean is based on 288 trials for one subject. (Results for ten additional subjects obtained over the SOA-range -160 to +240 msec are shown in Figure A4.9 below.)

Differences in error rates between the priming conditions followed a pattern which had some broad similarities to those of the response latencies; that is reliable case-priming effects were obtained only when primes were pre-exposed. Significant differences in error rate were obtained for the 40 (χ^2 = 27.11, p<.05), 80 (χ^2 = 55.99, p<.05), and 160 (χ^2 = 19.87, p<.05) msec SOAs. (The error differences obtained at -320 msec SOA were not found to be significant; χ^2 = 5.52, p>.05.) Apart from the condition-dependent effects occurring between SOAs of 40 and 160 msec Figure 4.9 suggests that error rates exhibit a general decline from an average of 0.125 at -480 msec to 0.072 at 480 msec.

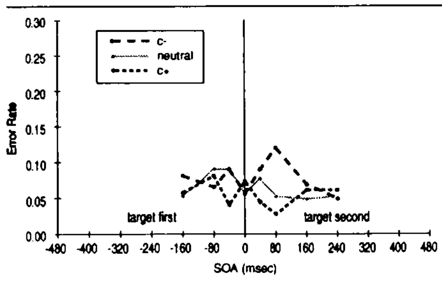


FIGURE A4.9. ERRORS: As for Figure 4.9: The variation in error rate for ten additional subjects obtained over the SOA-range -160 to +240 msec. (See Appendix 3 for further details.)

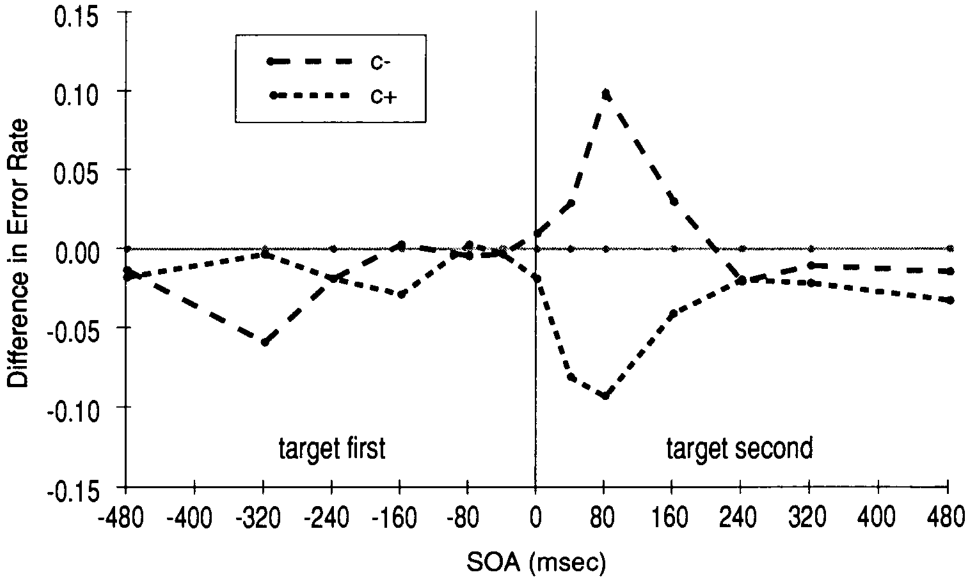


FIGURE 4.10. ERRORS: The difference in error rates for congruent and incongruent priming in relation to neutral priming as a function of prime-target stimulus onset asynchrony for Experiment 1. (Results for ten additional subjects obtained over the SAO-range -160 to +240 msec are shown in Figure A4.10 below.)

Additional-Subject Data

Results were obtained for ten additional subjects over a restricted SOA range (-160 to 240 msec). From Figures A4.7 to A4.10 it is apparent that the additional-subject data are qualitatively similar to the above main-subject data. Additionally this conclusion drawn from the graphical summaries is consistent with the further statistical details given in Appendix 3.

The most notable difference between main- and additional-subject data was that the latter were characterised by longer response latencies accompanied by fewer errors; this is apparent from comparing Figure 4.7 with Figure A4.7 (Page 151) and Figure 4.9 with Figure A4.9 (Page 154). Overall response times averaged 482.6 msec, that is 103 msec in

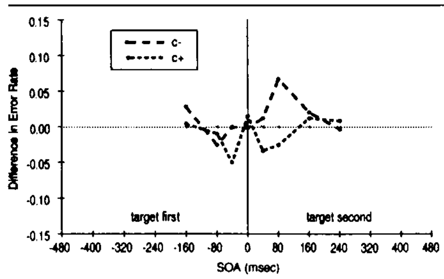


FIGURE A4.10. ERRORS: As for Figure 4.10: The difference in error rates in relation to neutral priming for ten additional subjects obtained over the SOA-range -160 to +240 msec. (See Appendix 3 for further details.)

excess of the main-subject data while the overall error rate was 0.073, compared with a figure of 0.110 for the main subject. These latter comparisons however relate to an SOA range of -480 to +480 msec with main-subject data compared with the -160 to +240 msec range with additional-subject data and in view of the time-course effects obtained must be interpreted advisedly.

Finally it is noted that all of the ten additional subjects considered the horizontal bars used occasionally for priming were no more similar to upper-case letters than they were to lower-case letters.

DISCUSSION

From the results it appears that both the latency and accuracy of case-decision responses is affected by pre-exposed case-priming information. In general, where case-priming effects were obtained, the fastest responses and the lowest rates of error were for congruently-primed targets while incongruent priming elicited the slowest responses with the highest error rate.

General Effect of the Presence of a Prime

With regard to the general effect of the presence of a prime the results obtained for those primes exposed 480 msec after their respective targets may appear to be of especial interest. If, as argued above, these primes may be regarded as effectively absent for the -480 msec trials then one conclusion that may be drawn from Figure 4.7 (Page 150) is that in general the presence of any prime appears to have a slowing effect upon response time regardless of whether it is pre- or post-exposed. However it should also be noted from a comparison with Figure 4.9 (Page 154) that this trend to slower response times over the range -480 to -240 msec is also matched by a downward trend in error rates. There is thus a possibility that a change in equilibrium between speed and accuracy of response may have occurred. This possibility is reinforced by a subjective observation that the longer negative SOAs effectively provide an incentive to 'beat the arrival of the prime' by responding early.

The downward trend in response time over the range -240 to 0 msec SOA (Figure 4.7, Page 150) is itself more difficult to account for. As with the remainder of the negative SOA range the slope appears to be negatively correlated with the trend in error rates apparent from Figure 4.9. However no solution can be offered as to why the local maximum in disruptivity is exhibited by primes which follow their respective targets by 240 msec.

The general tendency for any pre-exposed prime to result in longer response latencies than for post-exposure may be accounted for by the psychological refractory effect described earlier. This appears to reach a maximum over the +80 to +320 msec SOA region. From a comparison of Figures 4.7 and 4.9 a speed-accuracy tradeoff does not appear to operate in this region; apart from the selective effects (to be discussed shortly) the presence of a pre-exposed prime slows down case-responses without any accompanying variation in error rate.

In summary, then, although the presence of a prime may affect case-decision latencies in a way that may be broadly accounted for in terms of a speed-accuracy tradeoff and psychological refractivity, conclusions regarding the finer points relating to the general effect of the presence of a prime are difficult to draw.

Case-Congruency Effects

In addition to the more general considerations regarding the presence of a prime are considerations relating to congruency-dependent effects. An explanation for the observed effects has already been given in terms of typographic case information. Since a different combination of letters was used for each prime-target pair the only letter attributes that distinguished each of the priming conditions used were those features that typified typographic case. On this basis the possibility that typographic case is an identifiable physical attribute that may be used as a vehicle for further investigation of processing interactions is supportable since significant priming effects were obtained according to case condition. Earlier on, however, the possibility was raised that condition-dependent effects might arise indirectly from the more general effects of phasic alertness or psychological refractivity. In particular since the relative difference in the spatial distribution of letter features is greater with incongruent case-primes than with congruent ones, phasic effects may be comparatively greater in the incongruent condition. This suggestion is in accordance with such general findings that reaction time increases as relative stimulus level or area decreases (Hovland, 1936; Froeberg, 1907). From these latter studies it may be predicted that at very short SOAs the response times for case-congruent conditions (e.g., with a prime 'vftco' and a target 'lqhtp') may be lengthened while those for incongruent conditions (e.g., with a prime 'CILDP' and a target 'irhys') may be shortened. Although the effects of alertness or distraction may be small when letter primes are used, responses to a neutral condition where the prime consists of a row of dashes ('-----') may be more affected because of the greater difference in stimulus area in comparison to letter primes. If the effects of phasic alertness were to prevail responses in the neutral condition would be speeded and this would result in an apparent increase in any inhibitory effect obtained for for case-incongruent primes in comparison to the facilitatory effect that may be obtained for case-congruent primes. A similar but converse argument may apply to neutral primes in terms of their distracting effect, that is, if refractivity prevailed, facilitation of congruent primes would appear to increase and inhibition of incongruent primes diminish.

Although the significant differences between the case-congruent and case-incongruent conditions at the shorter positive SOAs may be at least partly accountable in the above terms, the position of the response latencies relative to the neutral condition is not. This is because the greatest relative difference in stimulus area for the neutral condition in comparison to both of the other priming conditions should give rise to either, a lowest ranking in response latency if indirect effects arising from phasic alertness prevailed, or, a highest ranking if refractivity prevailed. Since neither of these situations occurred the earlier explanation based upon typographic case information will be assumed; the effects of phasic alertness or refractivity being regarded as either counteractive or minimal.

Facilitation and Inhibition

At this point a further question arises as to whether the differences in response time signify both facilitation and inhibition (as opposed to varying degrees of inhibition, for example). Of relevance here is the reply by ten subjects who were additionally tested to a leading question regarding which of the two cases the horizontal bars more closely resembled. The fact that no subjects reported any association between either of the case-forms and the dash or minus signs that were used as primes in the neutral condition lends support to the effective neutrality of this condition. If the 'neutral priming' condition is truly neutral then it may be inferred that both facilitation and inhibition were obtained.

At this stage the possibility that facilitatory processes may be masked by inhibition from other sources must also be considered. In particular it is possible that a noticeable flicker from prime and target presentation at the shorter SOAs may distract and give rise to a general inhibitory effect which may bias the latencies for all priming conditions. This general effect may be large in comparison to any condition-dependent effect that may be indirectly obtained. The downward turn in response times at 480 msec SOA where the prime-target sequence takes on the appearance of two separate events rather than a flicker may be indicative of this. From the above arguments the view that both facilitatory and inhibitory priming effects arising directly from typographic case information may be occurring is held in relation to this experiment.

Relevance of Findings for Rival Processing Models

The occurrence of facilitatory effects is consistent with both the spreading-activation and PDP models of encoding as described. The obtained inhibitory effects are consistent with the predictions based upon response-competition and with PDP encoding mechanisms that involve inhibitory connections. If one is to attempt to distinguish between encoding models which are facilitatory-only and those that are also inhibitory then the present results need to be examined in more detail.

If it is argued that there is a dissimilarity in the time-course of inhibition and that for facilitation then in turn it may be suggested that different rather than similar and complementary processes are at work. From an examination of Figure 4.8 (Page 151) it may be argued that if dissimilarities are evident then they exist by virtue of the local variations in the time-course of facilitatory and inhibitory effects. Such dissimilarities might favour the facilitation-only encoding alternative and thus be contrary to the predictions arising from facilitation and inhibition characterised by the PDP encoding models. Further to this end it may be argued that if significant inhibitory effects occur within both encoding and responding mechanisms then it is plausible that the resultant magnitude of the combined inhibitory effects might be greater than that for a facilitatory effect that arose only at an encoding stage. In relation to this latter point, however, the relative inhibitory and facilitatory effects obtained may be of interest, if valid. For example it is apparent from Figure 4.8 that the maximum inhibitory effects obtained are smaller in magnitude than the maximum facilitatory effects. In addition it has already been noted that facilitation in response latency averages

11.09 msec in comparison to a 10.35 msec inhibition over the positive SOA range. Although the magnitude of the inhibition may be strictly less than that for facilitation there is, nevertheless, some similarity in magnitude. If the possibility that relatively small inhibitory effects occur within both encoding and responding stages is disregarded then the relative magnitudes of the inhibitory and facilitatory effects shown in Figure 4.8 (Page 151) is in accord with the predictions for the 'facilitation-only' model summarised earlier in Figure 4.4 (Page 142). However speculation on the basis of relative magnitudes is unwise at this stage and further discussion must await the results from later experiments.

The absence of any significant facilitatory effects for targets that coincide with or precede their respective primes may be argued to be in accordance with the basic predictions that may be made from models involving spreading-activation or pathway facilitation. Here the assumption is that a finite amount of time is necessary for one stimulus to raise the level of activation of the elements concerned. Furthermore, for a given stimulus attribute the simultaneous or subsequent arrival of a second stimulus has no effect upon the speed of processing of the first. In terms of the terminology adopted by Taylor (1977) the obtained time-course is consistent with the earlier predictions that were based upon a secondary, rather than primary, specific effect. Here the implication is that facilitation is attributable to completed, or at least partially completed, processing of a previously presented stimulus.

As with facilitation, inhibitory effects were obtained with pre-exposed primes. Although the longer response latencies for incongruent primes at zero SOA apparent in Figure 4.8 (Page 151) are non-significant the trend is in keeping with the earlier suggestion that according to the response-competition hypothesis inhibitory effects due to interfering covert responses might be expected at SOAs of zero and above.

It may also be apparent that the time-course of response latencies as shown in Figure 4.8 (Page 151) is to some extent similar to the time-course of error rates shown in Figure 4.10 (Page 155). That is, while no significant priming effects were obtained for negative SOAs this was not the case for the shorter positive SOAs. The difference between the error rate for the neutral and case-incongruent conditions may be explainable in terms of an initial response formation to the prime which in some cases is not suppressed by the time a response to the target is attempted. A similar mechanism with case-congruent primes may also result in a lower error rate in comparison to neutral primes. A further explanation of the error difference between neutral and case-congruent priming may be in terms of activated encoding mechanisms encoding congruent target stimuli more reliably.

That no significant differences in error rates were found at zero SOA for incongruent prime-target pairs is less easily explained in terms of conflicting response formation. However, at zero SOA, the combined prime-target array may be perceived differently from a prime followed by a target with the result that a response to the prime is not begun as if it were the target. In this situation it may be less likely that erroneous responses would be formed initially.

The discussion so far has focused mainly on the SOA range of -480 to about 160 msec. If the relatively long-term effects (i.e., in the latter half of the positive SOA range used) of prime information are also considered then the results in Figure 4.8 (Page 151) suggest that inhibitory effects are held fairly consistently for nearly least half a second. The error rate, however declines rapidly from a sharp maximum at 80 msec (Figure 4.9, Page 154). If response-competition is used to explain the inhibitory effects then these results suggest that while the suppression of an erroneous covert response may occupy responding mechanisms for nearly half a second the error effect that may result from the probability of a prime being responded to as if it were the target appears to diminish more rapidly. This might be predictable if it is assumed that a relatively long delay in target presentation does not interfere with the identification of the initial stimulus as the prime stimulus. With regard to the time-course of facilitation shown in Figure 4.8 (Page 151) it appears that the initial peak may be due to spreading-activation having a transient effect which may be attenuated by about 240 msec, perhaps due to a form of habituation. If the significant facilitation effect at 480 msec SOA is treated as reliable then this may indicative of another process beginning to take effect. One possibility here is the occurrence of slower-acting non-automatic effects mentioned in the context of Neely's (1977) work in Chapter 3.

The time-course data obtained in Experiment 1 for case-priming effects can be used to provide a comparison for within-attribute priming effects based on word-name. In accordance with the discussion in the last chapter decisions involving word-name do not necessarily involve access to semantic information relating to a word's reference; word-name simply refers to nominal identity. It was also argued that the mechanisms responsible for word-name identification are fundamentally similar to those responsible for other word-attributes such as case. Accordingly, a similar experimental procedure to the present one based on the categorisation of word-name should produce qualitatively similar time-course results. This is now considered in Experiment 2.

EXPERIMENT 2: Name-Priming of Name-Decision

In this experiment the effect of name-priming upon a speeded name-decision task was examined over the same range of prime-target onset asynchronies that was used in Experiment 1. The case-representing words 'upper' and 'lower' were used for both primes and targets. In order to reduce the probability of graphemic priming masking results when the same word is used both for prime and target all primes were presented in lower-case and all targets in upper-case. Table 4.4 shows the stimuli used and their arrangement according to priming condition. The occurrence of the same word, independently of typographic match, for

TABLE 4.4. The three priming conditions used in Experiment 2.

Condition	(Notation)	Prime	Target
name-congruent	(n+)	upper	UPPER
name-congruent	(n+)	lower	LOWER
name-incongruent	(n-)	lower	UPPER
name-incongruent	(n-)	upper	LOWER
neutral	(N)	ether	UPPER
neutral	(N)	ether	LOWER

both prime and target constituted name-congruent priming while the occurrence of a prime carrying name information that would elicit a response opposite to its respective target constituted incongruent priming. In an attempt to obtain a neutral priming condition the word 'ether' was used. This was chosen because it has the same same number of letters and syllables as the other stimuli and is readily approximated to the word 'either' which was assumed to relate equally to both target stimuli. Any response bias on the basis of semantic content of 'ether' was assumed to be unlikely because it was considered that the word's usual meanings are not readily associated with 'upper' or 'lower'.

PREDICTED PRIMING EFFECTS

In the task of pressing one or other of two response keys each arbitrarily assigned to one of a given set of two target words, it may be argued that word-name information, as distinct from other forms of information, may be of particular importance. Attention has been drawn to the importance of word-name information in view of tasks involving single-word stimuli that have been adopted in semantic-priming paradigms; these having implications with regard to the role of a word's semantic content. In the present experiment the effects that may arise from a prime carrying name information that is either identical to or different from that of the target are to be investigated. Although any priming effects may be due partly to semantic content there is also the possibility that name content may be partly or wholly responsible. There is thus an implied distinction here between name-priming and semantic-priming. Although semantic-priming may occur along with name-priming it is considered safer in view of possible mechanisms which have already been discussed to treat word meaning and word-name as separate entities and refer to priming only in terms of the form of information upon which the task is based. Although the present experiment may be classed as a semantic-priming experiment in which identity primes are used in the present context the distinction between semantic-priming and name-priming is regarded as important.

If it is assumed that the mechanisms responsible for word-name identification are fundamentally similar to those responsible for other word-attributes such as case then the present experiment based on the categorisation of word-name should produce qualitatively similar time-course results as the last experiment. The similarities to be expected include the relative facilitatory and inhibitory effects which should be detectable only for positive SOA values. These similarities are also assumed to be attributable to encoding and responding effects equivalent to those detailed in Experiment 1.

The main difference expected between the results from the two experiments is in overall response times to the targets. This follows from the assumption that the identification of a word-name involves more processing than that required for the identification of case-typifying features and that the amount of processing is reflected in the response latency. If it is assumed that processing in terms of word-name involves the activation of relatively more nodes or pathways than with case then it is also probable that any priming effects may be sustained over a relatively long period of time so that there should be a slower decay of facilitatory and inhibitory effects with increasing positive SOAs. The greater number of processing elements that may be involved with name-encoding may also have consequences with regard to the magnitude of any facilitatory or inhibitory effects obtained in comparison to case-priming.

An inherent problem with investigating the effect of word-attributes that form an integral part of the words that are used experimentally is that in some circumstances the occurrence of unwanted relationships between stimulus attributes may arise. In the present experiment such a relationship exists by virtue of the fact that both the prime and target words contain physical case information as well as name information. If the stimuli used in the present experiment as shown in Table 4.4 are considered in terms of their case-priming content as well as in terms of name-priming then it can be seen that the priming influences are potentially complex. If the n+ condition is taken as an example it can be seen that while the prime word contains congruent name information it also contains incongruent case information. A further complication arises by virtue of the case of the letters comprising the targets; for the target

'UPPER' the case is congruent while for the target 'LOWER' the case is incongruent. Although the unwanted case-priming effects may balance out, a measure of 'noise' may nevertheless be introduced and this will have to be considered when interpreting results.

METHOD

Apparatus and stimuli

The apparatus and the viewing conditions were identical to those used in Experiment 1. Stimuli were also of the same form and dimensions as Experiment 1; the only major difference was that the words 'upper' and 'lower' were used in place of the random letter strings and that the prime for the neutral condition consisted of the word 'ether' rather than a row of minus signs. All primes were in lower-case while all target stimuli were in upper-case. Table 4.4 (Page 164) shows the arrangement of stimuli according to the three experimental conditions used. The conditions were sequenced quasi-randomly so that there was no excessive clustering of any one experimental condition. Experimental trials were in blocks of 72 and similarly created practice trials were in blocks of 24.

Procedure

Apart from the instruction to categorise in terms of word-name rather than case the procedure was identical to that of Experiment 1. That is, the sequence comprising a single trial depended upon whether the primes were presented simultaneously or before and after the targets as shown in Figures 4.5a to 4.5c (Page 148). The occurrence of the word 'upper' was registered by pressing a right-hand response key while a left-hand response key was used for the word 'lower'. Reaction times were measured from the onset of the target and only those falling within a 200 to 1000 msec range were accepted for analysis.

The session began with the block of 24 practice trials, the SOA being set at the value to be used in the first experimental block. Practice trials were run until a suitable balance between speed and accuracy was attained; this was according to a criterion of at least 80% accuracy for mean response times of 700 msec or less. As with Experiment 1 SOAs of -480, -320, -240, -160, -80, -40, 0, 40, 80, 160, 240, 320, and 480 msec were used. The SOA was held constant within each block of trials but was altered randomly between blocks, each SOA value being used for two blocks. Each block of experimental trials took approximately five minutes to complete and was separated by a rest period of approximately three minutes; in total a session of some two hours. At the end of the session the subject was asked (in the form of a leading question) to say whether the word 'ether' which was occasionally visible was more similar to the word 'upper' or the word 'lower' and the response was noted. Experimental sessions were repeated so that a total of twelve sets of results were obtained.

RESULTS

From a total of 11,232 name-decision responses 3 fell outside the allotted 200 to 1000 msec interval. One of the 3 outlying responses was shorter than 200 msec and due to a false start while insufficient pressure on a response key accounted for the other two outliers. The 3 outliers were not considered in any further analyses including the compilation of error scores.

Response latencies

Significant name-priming effects were obtained; a 13(SOA) by 3(Congruency) ANOVA yielded, $F(2,10017) = 70.39$, $p<.001$. The main effect for SOA was also significant, $F(12,10017) = 87.68$, $p<.001$, as was the interaction between SOA and congruency, $F(24,10017) = 9.80$, $p<.001$.

As with Experiment 1 the above data were examined in terms of prime-target order. An SOA by Congruency ANOVA for pre-exposed primes (SOA range +40 to +480 msec) indicated significant name-priming effects, $F(2,4586) = 51.91$, $p<.001$ while no significant effects were obtained for post-exposed primes (SOA range -480 to -40 msec), $F(2,4679) = 2.07$, $p>.001$. Interaction between SOA and congruency was neither significant for pre-exposed primes $F(10,4586) = 1.11$, $p>.001$, nor in the case of post-exposure, $F(10,4679) = 1.22$, $p>.001$ in the case of post-exposure. While name-decision latencies were not affected by prime-target onset asynchrony for pre-exposed primes, $F(5,4586) = 6.78$, $p>.001$, the reverse was found for post-exposed primes $F(5,4679) = 93.61$, $p<.001$.

The mean correct response times for each of the SOA-levels for each priming condition are represented in Figure 4.11. As with Experiment 1 difference scores were obtained by subtracting the means for the case-congruent and case-incongruent priming conditions from the means for the neutral condition. These differences are shown in Figure 4.12 with the terms 'inhibition' and 'facilitation' used with reference to positive and negative differences as before. Similarly the SOA of the prime and target was measured in relation to the onset of the target so that prime pre-exposures are shown by positive SOA values while prime post-exposures are shown by negative SOAs.

Figures 4.11 and 4.12 suggest a reliable pattern of name-priming effects. This reliability was confirmed by a series of one-way ANOVAs carried out across congruency conditions for each SOA followed by the use of the Newman-Keuls method when a significant ($p<.05$) congruency effect was obtained for a given SOA. As in the previous experiment the results of these tests will be reported only when the significance or non-significance of an effect may not be obvious from the above representations; the 'Q' statistic, being obtained from the Newman-Keuls procedure and a significance criterion of $p<.05$ being used.

No significant differences were found between the name-decision RTs obtained for any of the three priming conditions over the SOA range -480 to 0 msec as is evident from Figures 4.11 and 4.12. This contrasts with the condition-dependent effects obtained for SOAs of 40 msec and

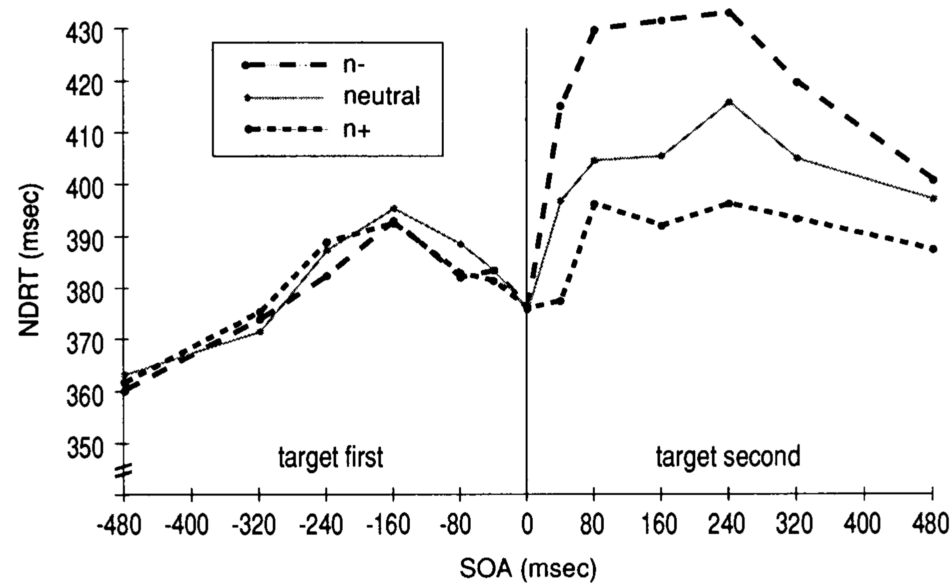


FIGURE 4.11. RESPONSE TIMES: Mean response times for correct name-decisions as a function of priming condition and prime-target stimulus onset asynchrony for Experiment 2. Each mean is based on 288 trials for one subject. (Results for ten additional subjects obtained over the SOA-range -160 to +240 msec are shown in Figure A4.11 below.)

above where in relation to neutral priming NDRTs for congruent primes averaged 13.7 msec shorter while NDRTs for incongruent primes were 17.2 msec longer. All condition-dependent effects obtained in the positive SOA range were found to be significant except for the neutral and incongruent priming at 480 msec SOA, Q,779=1.32, p>.05. The difference in response times for congruently-primed targets in relation to the neutral condition was subject to minor variation over the positive SOA range, although the curve in Figure 4.12 suggests no obvious

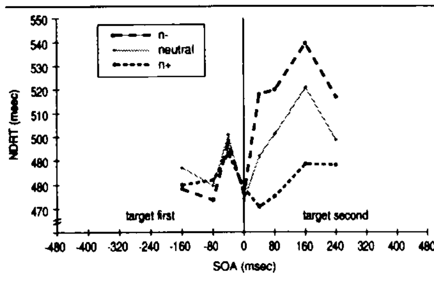


FIGURE A4.11. RESPONSE TIMES: As for Figure 4.11; mean correct name-decision response times for ten additional subjects over the SOA-range -160 to +240 msec. Each mean is based on 288 trials. (See Appendix 3 for further details.)

overall trend. For incongruently-primed targets, priming in relation to the neutral condition reached a maximum of 26.2 msec at 160 msec SOA Q,760=8.6, p<.05 before falling to the non-significant level of 3.7 msec at 480 msec SOA.

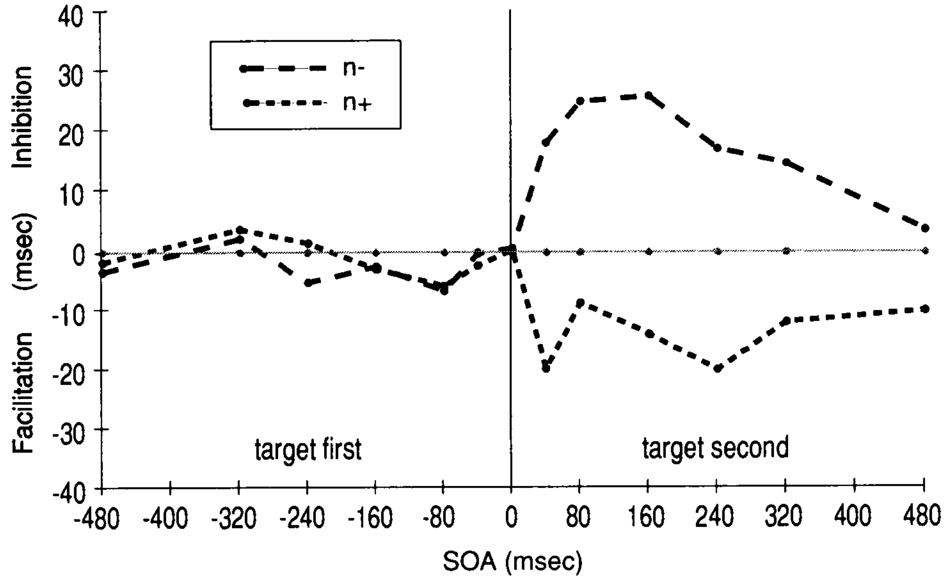


FIGURE 4.12. RESPONSE TIMES: The difference in mean response times for congruent and incongruent name-priming in relation to neutral priming for correct name-decisions as a function of prime-target stimulus onset asynchrony for Experiment 2. (Results for ten additional subjects obtained over the SOA-range -160 to +240 msec are shown in Figure A4.12 below.)

Observations regarding the variation of response time with SOA (rather than the variation of the priming effect relative to the neutral condition) may be made, albeit with the assumptions applicable to Experiment 1. That is, because the sequence of trial-blocks was randomly varied with regard to SOA then overall any systematic variation of carry-over effects resulting from such factors as practice or fatigue is assumed to be minimal. From Figure 4.11 it is apparent that a minimum disruptive

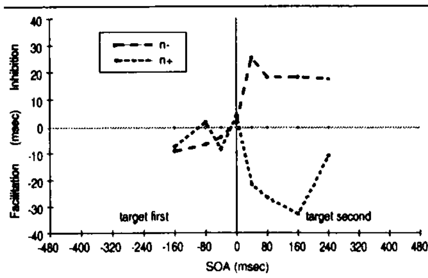


FIGURE A4.12. RESPONSE TIMES: As for Figure 4.12; the difference in mean response times in relation to neutral priming for ten additional subjects over the SOA-range -160 to +240 msec. (See Appendix 3 for further details.)

effect on response latency was obtained at an SOA of -480 msec and, as with the last experiment, it was observed that very few primes were visible at this SOA value. The explanation that trial-terminating responses were made before the occurrence of a prime is also supported statistically since at an SOA of -480 msec the mean response time across priming conditions was only 361.7 msec, SD=46.4. The overall response latencies rise linearly from the mean of 361.7 msec at -480 msec to a maximum of 393.7 msec at -160 msec SOA before falling to a mean of 376.1 msec at zero SOA. For SOAs above zero response latencies follow an inverted 'U' function with condition-dependent maxima occurring at around 320 msec SOA. It is also noted that, across all SOAs, the name-decision RTs obtained in the present experiment averaged 391.2 msec while the case-decision RTs of Experiment 1 averaged 379.6 msec. This 11.6 msec difference in response times is, however, at best only indicative of any relative differences in case- and name-decision speeds since the experiments were run at different times and not designed with such direct comparisons in mind.

Error rates

The error rates for the three priming conditions are expressed in Figure 4.13 as a proportion of the total responses for each condition at each SOA-level. In Figure 4.14 the same data are presented in terms of the congruent and incongruent priming conditions in comparison to the neutral condition. The consistencies apparent in Figures 4.13 and 4.14 were largely in agreement with a series of chi-square tests, the results of which are reported only when the significance or non-significance may not be obvious.

As in the previous experiment the differences in error rates between priming conditions followed a pattern which had similarities to those for the response latencies. Reliable effects were only obtained when primes preceded the targets. The difference in error rates between the incongruent and neutral conditions appear substantially more marked than between the neutral and congruent priming conditions. With the exception of the +480 msec SOA (χ^2 = 2.06, p>.05) significant differences in error rate were found over the entire positive SOA range. Apart from the maxima for the incongruent priming condition it appears

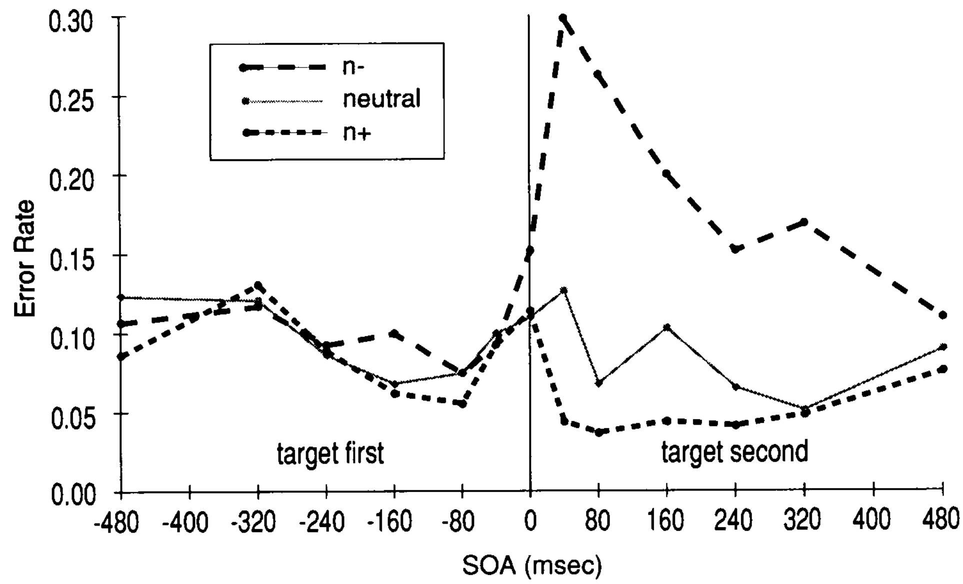


FIGURE 4.13. ERRORS: The variation in error rate for name-decisions according to priming condition and stimulus onset asynchrony for Experiment 2. Each mean is based on 288 trials for one subject. (Results for ten additional subjects obtained over the SOA-range -160 to +240 msec are shown in Figure A4.13 below.)

from Figure 4.14 that error rates exhibit a small but general decline from an average of 0.107 at -480 msec to 0.093 at +480 msec.

Additional-Subject Data

As with Experiment 1 results were obtained for ten additional subjects over the restricted SOA range -160 to 240 msec. Overall name-decision response times averaged 492.4 msec, that is nearly 101 msec in excess of the main-subject data. The overall error rate was 0.062. This compares

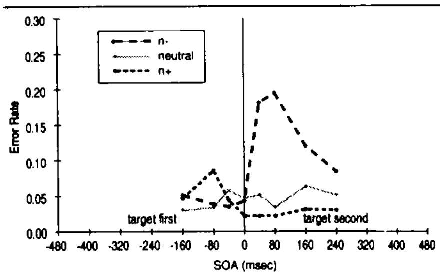


FIGURE A4.13. ERRORS: As for Figure 4.13; the variation of error rate for ten additional subjects obtained over the SOA-range -160 to +240 msec. (See Appendix 3 for further details.)

with a figure of 0.117 for the main subject. The increase in response latency accompanied by a lower error rate for the additional subjects in comparison to the main subject matches a similar trend for the additional-subject data obtained in Experiment 1. From Figures A4.11 to

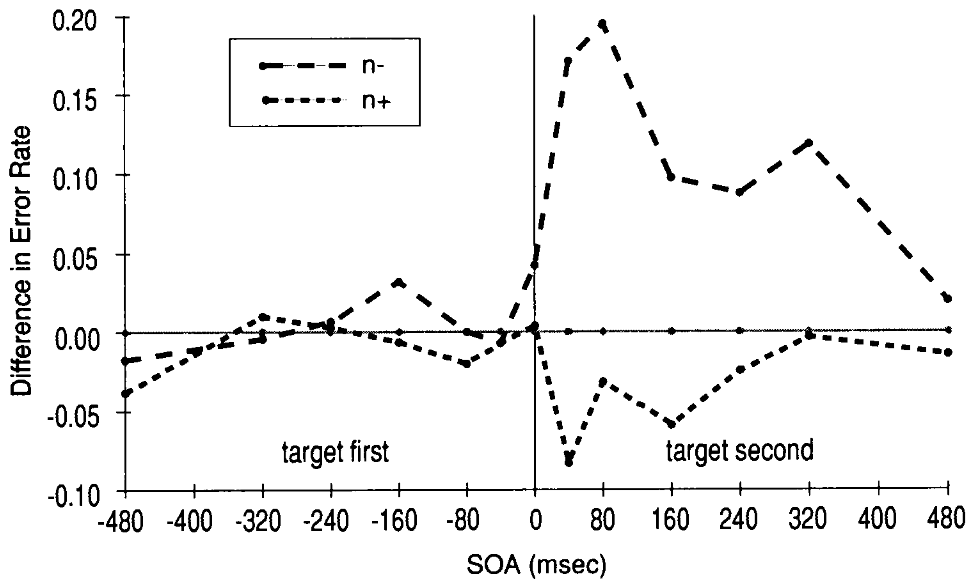


FIGURE 4.14. ERRORS: The difference in error rates for congruent and incongruent priming in relation to neutral priming as a function of prime-target stimulus onset asynchrony for Experiment 2. (Results for ten additional subjects obtained over the SOA-range -160 to +240 msec are shown in Figure A4.14 below.)

A4.14 it appears that the priming effects obtained with the additional subjects were qualitatively similar to those obtained for the main subject. Again this is further supported by the more detailed results given in Appendix 3. It is also noted that all ten additional subjects considered the word 'ether' to be no more similar to the word 'upper' than to the word 'lower'.

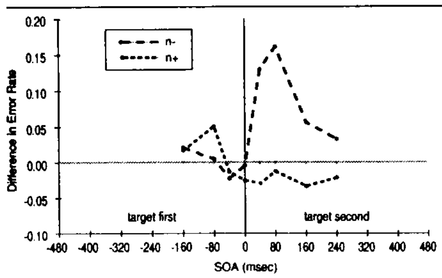


FIGURE A4.14. ERROR RATES: As for Figure 4.14; the difference in error rates in relation to neutral priming for ten additional subjects over the SOA-range -160 to +240 msec. (See Appendix 3 for further details.)

DISCUSSION

As with case-priming the present results suggest that the presence of name-primes affects the speed and accuracy of name-categorisation tasks. If the validity of the neutral priming condition is argued on similar grounds to those for Experiment 1 then it may again be assumed that both speeding and slowing effects occurred. Since no significant name-priming effects for targets that coincided with or preceded their respective primes were obtained they may be described as being 'secondary' in nature (cf., Taylor, 1977).

Although the pattern of response latencies for name-decisions has similarities to that for case-decisions a difference that is observable is that the reaction time for name-decisions averages approximately 12 msec longer. Such an increase in response time applies for all priming conditions which are equivalent in terms of congruency across the two experiments. Although similar error rates occurred in the two experiments indicating a similar speed/accuracy response criterion the comparison of absolute response times must be treated with caution. Nevertheless the observation is supportive of the earlier assumption that the identification of a word-name involves more processing than that required for the identification of case-typifying features. The prediction that a slower decay of facilitatory and inhibitory effects with increasing positive SOAs may result if processing in terms of word-name involves the activation of relatively more nodes or pathways than case-processing is difficult to verify. If name-priming is sustained over a relatively long period of time its presence may be masked by the effect of the continued presence of the primes used at the longer SOAs. If habituation results from the continued presence of a prime then the results from the two experiments carried out so far suggest that measurements at SOAs in excess of 480 msec would be necessary to detect this.

The trend across Figure 4.11 shows that the presence of any pre-exposed prime appears to have an inhibitory effect upon name-decision response latency. The similar pattern of response times and error rates of the present experiment in comparison to Experiment 1 invites a similar account to that already detailed. That is, regarding the general effect of prime presence, a speed-accuracy tradeoff may account for the negative correlation between response time and error rates apparent from a comparison of Figures 4.11 and 4.13 (Pages 170 and 173). Similarly the overall increase in response latencies for pre-exposed primes may be accounted for in terms of psychological refractivity. As with Experiment 1 the recurrence of a local maximum in response latency in the region of -240 msec SOA (Figure 4.11, Page 170) is again not easily explained.

If the reporting that the string 'ether' was no more associated with the word 'upper' than with the word 'lower' is taken to suggest a truly neutral condition for the present experiment then facilitatory and inhibitory effects may be assumed. The probability that selective facilitatory or inhibitory effects arise from the occurrence of low-level graphemic attributes such as those involved in case-recognition is reduced on account of the prime and target words being in a different typographic case. In this way case differences are spread evenly across priming conditions. This incongruency might result in a general increase in both error rate and response latency. However the factor of case-incongruency alone accounting for longer name-decision latencies in comparison to case-decision latencies may be counter-argued on the grounds that name-decision latencies were some 5 msec in excess of case-decision latencies for post-exposed primes (Figures 4.7 and 4.11, Pages 150 and 170). This latter argument, of course, assumes that incongruent priming information has no effect over the greater part of the negative SOA range.

It may be noted that even after the extensive practice at word identification implicated by the repeated trials the average name-decision latency was some 12 msec in excess of case-decision latency. In accordance with the earlier predictions this may be taken to suggest that the analysis of name-input may involve different mechanisms, or, involve more extensive processing than with case-input. With these observations in mind and in view of word-name being the controlled priming attribute the selective priming effects may be assumed to be attributable to name content rather than other stimulus attributes. If this assumption holds then word-name may be used as a priming attribute in the course of further investigation.

The relative facilitatory and inhibitory effects as shown in Figure 4.12 are, as predicted, qualitatively similar to those obtained with case-priming in Experiment 1. In this respect the possibility of facilitatory and inhibitory encoding effects remains, as does a response-competition account for inhibitory effects. A further important similarity is reflected in the time-course of results; relative facilitatory and inhibitory effects were only detected for positive SOA values. This, again, supports predictions based on models involving spreading-activation. Priming can still be viewed as a specific effect (Taylor, 1977) resulting from the completed, or at least partially completed, processing of a previously presented stimulus.

In summary, then, the similarities in name-priming effects with those obtained for case-priming suggest, as predicted, that similar mechanisms may be responsible with both types of word-attribute. If the priming effects obtained in the present experiment are interpreted similarly to those in the previous experiment then the basic predictions relating to facilitation that may be made from models involving spreading-activation or PDP are again supported. The possibility that inhibition may be due either to response-competition, or, the inhibitory encoding processes characteristic of some PDP models is also consistent with these data. The time-course of priming effects suggests that facilitation and inhibition results from the completed or partly completed processing of previously presented name information.

EXPERIMENT 3: Name-Priming of Case-Decision

In this experiment the words 'upper', 'lower' and 'ether' are used as congruent, incongruent and neutral primes on case-decisions carried out on random letter strings which are displayed, as in Experiment 1, entirely in upper-case or in lower-case. An illustration of each priming condition is given in Table 4.5. Primes and prime conditions are identical with Experiment 2, but now the conditions are described in terms of the congruency of the prime's name-attribute with the target case as shown

TABLE 4.5. The three priming conditions used in Experiment 3.

Condition	(Notation)	Prime	Example of Target
name-congruent	(n+)	upper	YGSRO
name-congruent	(n+)	lower	hjoti
name-incongruent	(n-)	lower	XBLNT
name-incongruent	(n-)	upper	rejhf
neutral	(N)	ether	FPAWR
neutral	(N)	ether	lpevo

in the table. One assumption that is implicit in any cross-attribute priming effect obtained is that the experimental subject is either already aware of the relationships between the physical case and the priming words or that through given information and practice trials the relationships will become quickly established. The use of the word 'ether' as a neutral prime was considered unlikely to create a strong bias in responses for similar reasons as with the second experiment.

Relationship Between Prime and Target Information

In the present cross-attribute priming paradigm the inclusion of case information with word-name information is, of course, unavoidable unless a spoken presentation is used. Since the time durations required for a spoken stimuli would be well in excess of the shorter SOAs necessary for the time-course range that is under scrutiny this method of presentation was not used. In answer to the problem concerning double priming effects it is possible to use priming stimuli of both typographic cases and create a number of priming conditions in order to provide a relatively comprehensive control. Alternatively, as with the present experiment, all the prime words may presented in the same case with, as deducible from Table 4.5, half the trials in each of the name-priming conditions being case-congruent and the other half being case-incongruent. Although name-priming will be confounded with case-priming, any case-priming effects will be assumed, for the moment, to balance-out. Although this latter option may conceal some important effects of double priming it does have the advantage that considerably fewer priming conditions are involved. The conditions as given in Table 4.5 are thus used in the first instance to establish whether name-priming effects on case-decision are detectable and also used to obtain a time-course of any overall effects.

PREDICTED PRIMING EFFECTS

Encoding and Responding Effects

If cross-attribute priming is to be predicted at the encoding stage then a link between the mechanisms responsible for verbal and nonverbal information is required. In this respect the dual- and single-encoding structures introduced in Chapter 3 are relevant. Cross-attribute priming effects are predictable with both models. With a single-encoding system such as that represented by the sensory-semantic model verbal input is assume to activate semantic codes which in turn activate nonverbal codes (Figure 1.5, Page 51). Paivio's dual-coding model allows for verbal codes to be communicated to the image system via referential processing (Figure 1.6, Page 53). With both encoding models it is again assumed that the encoding of case and name information may be facilitated or inhibited according to those principles relating to the relevant microstructures and are independent of the original form of the priming information.

As with the earlier experiments it is also assumed that responding processes are subject to interfering effects arising from incongruent cross-modality information in a similar manner as with incongruent within-modality information. In view of the earlier discussion of the classical Stroop findings this latter assumption may be claimed to be reasonable.

In view of the above assumptions it is predicted, as with Experiments 1 and 2, that case-decisions which are congruently name-primed may be facilitated due to encoding effects while those incongruently-primed may be subject to inhibition according to the different encoding and response processing models that have been adopted. The predictions of the resultant effects of encoding and responding mechanisms according to these models are summarised in Figure 4.15. These predictions have been formulated in an analogous way to Experiments 1 and 2, and, as might be expected, it can be seen that there are close parallels with the earlier within-modality predictions given in Figures 4.2, 4.3 and 4.4 (Pages 140, 141 and 143 respectively).

Predicted Time-Course of Encoding and Response Effects

Although the magnitude of the cross-attribute priming effects could be expected to be similar to the within-attribute effects, by way of contrast it could also be argued that the time-courses should be distinctly different. The time-courses of the results obtained in Experiments 1 and 2 suggest

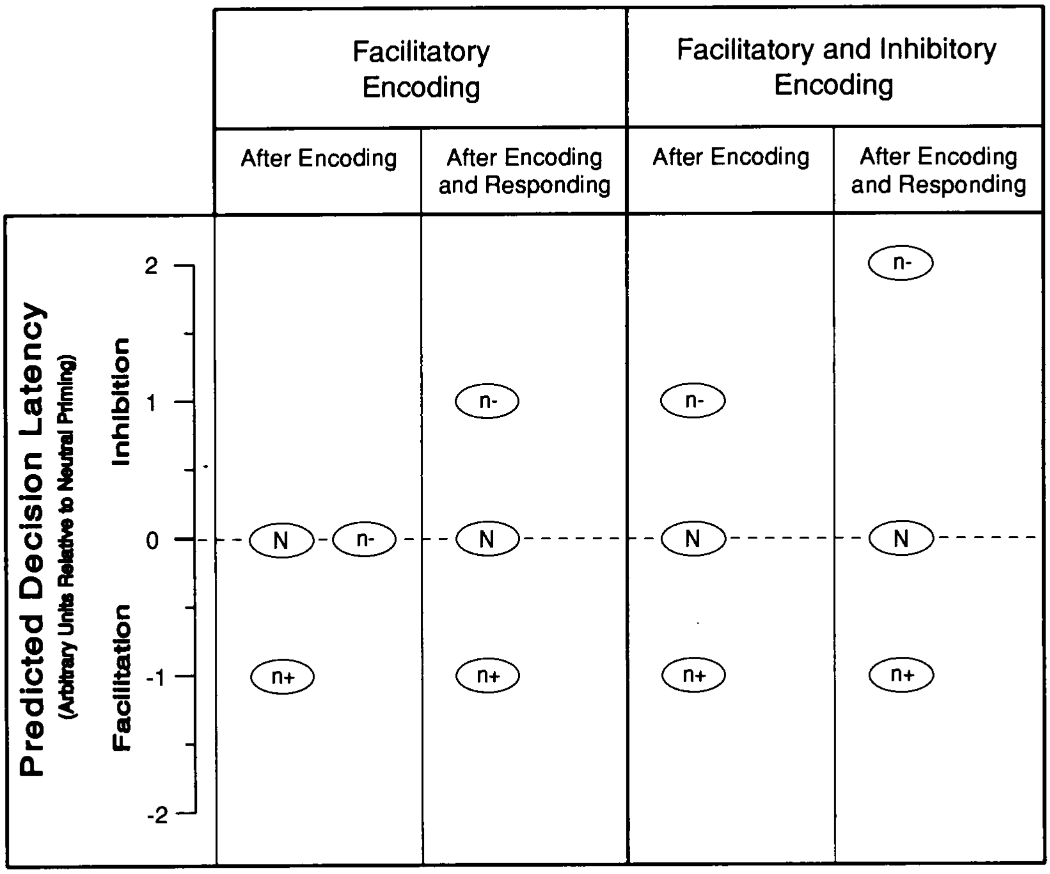


FIGURE 4.15. A schematic representation of the relative resultant effects of encoding and responding processes upon name-decision latencies according to priming condition. ('n+' = name-congruent priming, 'n-' = name-incongruent priming, 'N' = neutral priming.)

that priming effects arise from either completed or partially completed processing of previously presented prime information rather than arising from the ongoing processing of a prime. If this latter inference is also applicable to cross-attribute priming effects then the time-course of any effects will be determined by the nature of the structure which allows communication between nonverbal and verbal codes.

If a dual-coding model similar to that proposed by Paivio & Begg (1981) is taken as a linking structure (Figure 1.6, Page 53) then referential processing is possible once the representational codes for verbal or nonverbal input become available. On this basis it may be argued that the referential links that exist between the verbal and nonverbal systems allow priming to be of a 'secondary' nature (Taylor, 1977). On this basis if a prime precedes a target it is likely to have an effect upon response time. This dependence upon temporal precedence may be contrasted with the Taylor's 'primary' specific effect which requires temporal proximity; the order of presentation of prime and target not being relevant. However with cross-attribute priming where name information is used to prime a task based upon case information temporal precedence is dependent upon the time for a word to activate its respective logogen plus the time for the representational verbal code to connect with the image system. If the time for the processing of verbal information exceeds that for nonverbal information, as a comparison of the response time in Experiments 1 and 2 suggests, then the effect of name-priming information should be delayed. The extent of the delay may be similar in magnitude to the difference in times required for verbal and nonverbal processing. If the results of Experiments 1 and 2 are used for guidance in this matter then it is expected that name-priming effects upon case-decision would only be obtained for SOAs in excess of a few tens of milliseconds.

In the case of a single-encoding model such as that suggested by Nelson et al. (1977) it can also be argued that a relatively large time duration would be necessary for interaction to occur between verbal and nonverbal stimulus components via the semantic route. If information is at a relatively late stage of analysis before going via the semantic route it may be argued that the time-course of any priming effects would depend upon the relative speeds of encoding of name and case information. If a comparison of the overall response times for Experiments 1 and 2 is again taken to suggest that name-encoding requires more time than case-encoding then a prime carrying name information would have to precede a target in order to have any effect on a case-decision; the time-course representing this would, as with the dual-coding model, be characterised by effects obtainable only for SOAs greater than zero. If an attempt were to be made to quantify such a time-course then, again, the results of Experiments 1 and 2 may suggest very crudely that name information would have to precede a target by at least a few tens of milliseconds for significant priming effects on a case-decision task to be obtainable.

Both the single- and dual-coding models, then, predict a delay due to encoding in name-priming of case-decision in comparison to the within-attribute priming effects obtained in the first two experiments. Although the extent of the delay is difficult to quantify precisely it is possible that encoding effects may be obtained at SOAs in excess of 40 msec. This therefore contrasts with the within-attribute experiments where significant effects were obtained at 40 msec SOA.

If the response-competition hypothesis is used as before to predict the time-course of responding effects then the longer time for the processing of verbal input in comparison to nonverbal input will have similar repercussions for responding as well as encoding effects. That is if inhibitory responding effects are obtained then these may, again, only be significant at SOAs in excess of 40 msec.

Summary

In summary, then, it has been argued that while similar mechanisms are responsible for the magnitude of priming effects occurring across stimulus attributes as well as within attributes there may be a difference in the time-course of any effects. In particular it is suggested that with both single- and dual-coding models it is possible that significant encoding and responding effects may only be obtainable at SOAs greater than 40 msec duration. Experiment 3, then, aims to test these predictions.

METHOD

Apparatus and Stimuli

The apparatus and viewing conditions were identical to those used in Experiment 1. Stimuli were also of the same form and dimensions as Experiment 1. Primes consisted of the words 'upper', 'lower' and 'ether'; the latter being used in the neutral priming condition. Targets consisted of random letter strings, a different string for each trial. Examples of the three experimental conditions used have been shown in Table 4.5 (Page 178). The conditions, as with the other experiments, were sequenced quasi-randomly so that there was no excessive clustering of any one experimental condition. Experimental trials were in blocks of 72 and similarly created practice trials were in blocks of 24.

Procedure

A procedure largely identical to that of the previous two experiments was adopted. However familiarity with the use of the words 'upper' and 'lower' to denote specific typographic case forms was initially checked by asking the subject to categorise verbally a list of letter strings similar to those to be used as targets in the experimental trials. The list comprised ten upper-case and ten lower-case strings arranged randomly in terms of case but presented sequentially on the display monitor. The experiment was continued if at least eighteen of the twenty letter-strings were categorised correctly.

The sequence comprising a single trial depended upon whether the primes were presented simultaneously or before and after the targets as shown in Figures 4.6a to 4.6c (Page 148). Again the purpose of the experiment was disclosed insofar that it was said that the effect of the presence of words upon the response times to letter-strings was being investigated. Information was given that a target string of letters would appear centrally between two markers and that a word or string of characters to which no response was required would appear just below the target. Subjects were instructed to respond according to typographic case of the target. The occurrence of an upper-case letter string was registered by pressing a right-hand response key while a left-hand response key was used for lower-case. Reaction times were measured from the onset of the target and only those falling within a 200 to 1000 msec range were accepted for analysis.

The session began with a block of 24 practice trials, the SOA set at the value to be used in the first experimental block, the practice trials run until a suitable balance between speed and accuracy was reached, again the criterion being at least 80% accuracy for mean response times of 700 msec or less. As with Experiments 1 and 2, SOAs of -480, -320, -240, -160, -80, -40, 0, 40, 80, 160, 240, 320, and 480 msec were used. The SOA was held constant within each block of trials but altered randomly between blocks, each SOA value being used twice. A block of experimental trials took between five and ten minutes to complete and was separated by a rest period of approximately three minutes. An experimental session lasted approximately two hours. At the end of the session the subject was asked (in the form of a leading question) whether the word 'ether' which was occasionally visible was more suggestive of upper-case or lower-case letters and the response was noted. Experimental sessions were repeated so that a total of twelve sets of results were obtained.

RESULTS

Out of a total of 11,232 case-decision responses 9 fell beyond the allotted 200 to 1000 msec interval. Five out of the 9 outliers were shorter than 200 msec and were due to false starts while insufficient pressure on a response key or minor lapses in attention accounted for the remainder. The 9 outliers were not considered in any further analyses including the compilation of error scores.

Response Latencies

Significant name-priming effects were obtained; a 13 (SOA) by 3 (Congruency) ANOVA yielded an $F(2,10007) = 24.40$, $p<.001$. The main effect for SOA was also significant, $F(12,10007) = 48.54$, $p<.001$, as was the interaction between SOA and congruency, $F(24,10007) = 4.37$, $p<.001$.

The above data were examined in terms of prime-target order. An SOA-by-Congruency ANOVA for pre-exposed primes over the SOA range +80 to +480 msec indicated significant name-priming effects, $F(2,3851) = 60.76$, $p<.001$ while no significant effects were obtained for post-exposed primes over the SOA range -480 to -40 msec, $F(2,4625) = 0.56$, $p>.001$. Interaction between SOA and Congruency was non-significant for the pre-exposed primes $F(8,3851) = 1.26$, $p>.001$, and non-significant $F(10,4625) = 0.50$, $p>.001$ in the case of post-exposure. The main effect for SOA for pre-exposed primes was found to be non-significant, $F(4,3851) = 3.68$, $p>.001$ while that for the post-exposed primes was significant, $F(5,4625) = 32.17$, $p<.001$.

The mean correct case-decision response times for each SOA level for each priming condition are represented in Figure 4.16. Difference values, as with the first experiments, were obtained by subtracting the means for the name-congruent and name-incongruent priming conditions from the means for the neutral condition. These differences in response time are shown in Figure 4.17 with the terms 'inhibition' and 'facilitation' referring to positive and negative differences respectively. As before, the SOA of the prime and target was measured in relation to the onset of the target so that positive SOA values indicate prime pre-exposures while negative SOAs show prime post-exposures.

A reliable pattern of name-priming effects is evident from Figures 4.16 and 4.17. As in the previous experiments a series of one-way ANOVAs was carried out across congruency conditions for each SOA and followed by the use of the Newman-Keuls method when a significant ($p<.05$) congruency effect was obtained for a given SOA. These tests confirmed the significance or non-significance of those effects ($p<.05$) readily discernible from the graphs. The results of the tests are reported when the degree of significance may not be obvious.

It is noticeable from Figures 4.16 and 4.17 that non-significant differences in condition-dependent effects were obtained for the

+40 msec SOA in addition to the SOA range -480 to 0 msec. This contrasts with Experiments 1 and 2 where significant condition-dependent effects were obtained at +40 msec SOA. For SOAs of +80 msec and above congruent CDRTs averaged 9.7 msec less than

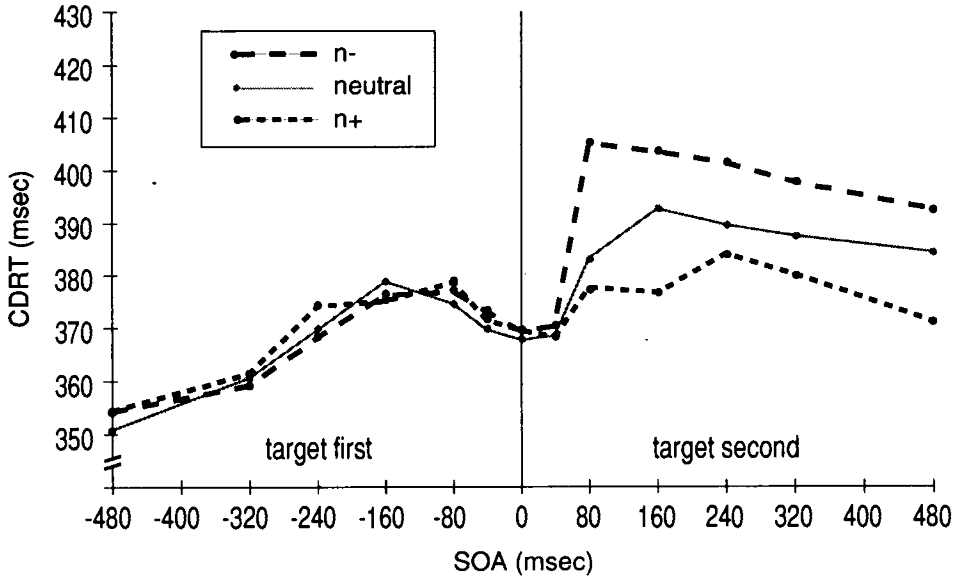


FIGURE 4.16. RESPONSE TIMES: Mean response times for correct case-decisions as a function of priming condition and prime-target stimulus onset asynchrony for Experiment 3. Each mean is based on 288 trials for one subject. (Results for ten additional subjects obtained over the SOA-range -160 to +240 msec are shown in Figure A4.16 below.)

those for the neutral condition while incongruent name-priming resulted in CDRTs averaging 12.3 msec longer than the neutral condition. All incongruent priming effects for SOAs of +80 msec and above were found to be significant. Congruent priming effects, however, were only significant at 160 msec SOA, Q,761=4.74, p<.05, and at 480 msec, SOA, Q,766=4.31, p<.05. Apart from an initial peak of 21.8 msec at 80 msec SOA the difference in response times for incongruently-primed targets in relation to the neutral condition remained fairly constant over the +80 to

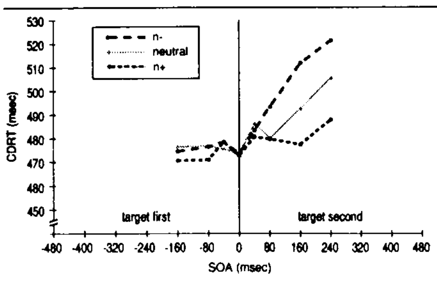


FIGURE A4.16. RESPONSE TIMES: As for Figure 4.16; mean correct case-decision response times for ten additional subjects over the SOA-range -160 to +240 msec. Each mean is based on 288 trials. (See Appendix 3 for further details.)

+480 msec SOA range. The time-course for congruent priming effects was subject to some variation. From Figure 4.17 it may be noted that the difference in latencies between the neutral and congruent priming conditions reaches a maximum of 16.3 msec at 160 msec SOA and a

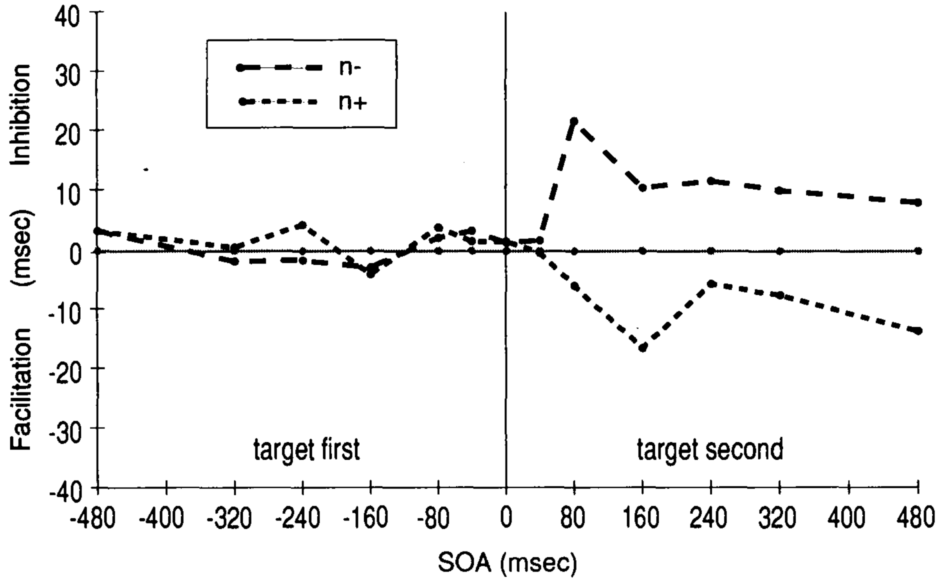


FIGURE 4.17. The difference in mean case-decision response times for congruent and incongruent priming in relation to neutral priming as a function of prime-target stimulus onset asynchrony for Experiment 3. (Results for ten additional subjects obtained over the SOA-range -160 to +240 msec are shown in Figure A4.17 below.)

minimum of 5.5 msec at +240 msec SOA before gradually increasing again over the +320 and +480 msec SOA-levels.

As with the previous experiments the variation of response time with SOA (rather than the variation of priming relative to the neutral condition) may be considered, assuming as before that any systematic variation in terms of carry-over effects is minimal. On this basis, Figure 4.16 indicates that a minimum disruptive effect on response

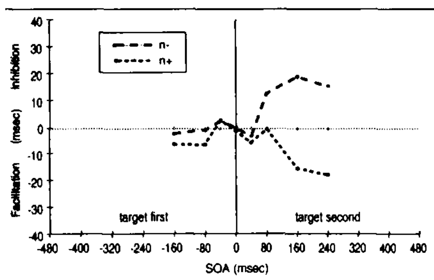


FIGURE A4.17. RESPONSE TIMES: As for Figure 4.17; the difference in mean response times in relation to neutral priming for ten additional subjects over the SOA-range -160 to +240 msec. (See Appendix 3 for further details.)

latency was obtained at an SOA of -480 msec. As before it was observed that very few primes were visible at this SOA value since trial-terminating responses were made before the occurrence of a prime; the mean response time across priming conditions being only 353.7 msec, SD=43.2. Response latencies increased from 353.7 to 377.3 msec over the SOA range -480 to -80 msec and then decreased to 369.4 msec at zero SOA. For all three priming conditions response latencies remained at about 369 msec between zero and +40 msec SOA. The remainder of the positive SOA range for the incongruent condition was characterised by a sharp increase in response latency of about 35 msec before levelling out. The latencies for the neutral priming condition followed a similar, although less extreme, pattern while latencies for congruently-primed targets increased by about 9 msec to about 379 msec across the remaining SOA range.

The case-decision reaction times obtained in the present experiment averaged 376.6 msec; this nearly matched the average of 379.6 msec obtained for Experiment 1. It will be similarly recalled that the name-decision reaction times for Experiment 2 averaged 391.2 msec. Again comparison of response times across experiments are made with caution since the experiments were run at different times and not designed so that such comparisons could be reliably made.

Error Rates

Figure 4.18 shows the error rates for the three priming conditions as a proportion of the total responses for each condition at each SOA-level and Figure 4.19 shows the error rates for the congruent and incongruent priming conditions in comparison to the neutral condition. The statistical significance of the effects suggested by the consistencies apparent in Figures 4.18 and 4.19 was largely in agreement with the results of a series of chi-square tests, the results of which are reported when the significance or non-significance may not be obvious.

As before the pattern of differences in error rates between the priming conditions has similarities to the pattern of response latencies. Reliable name-priming effects were only obtained when primes preceded the targets. Again, as in the previous experiments, the difference in error

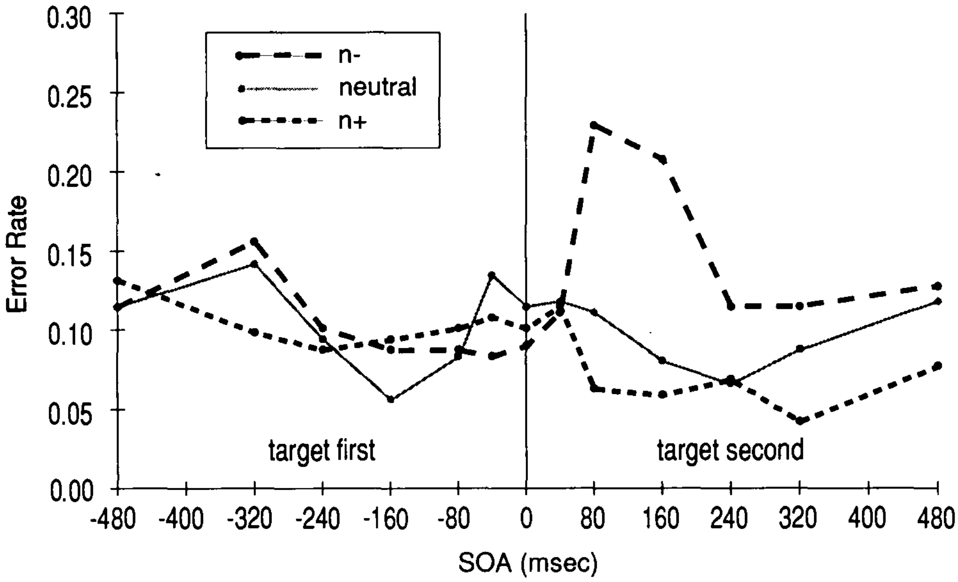


FIGURE 4.18. ERRORS: The variation in error rate for case-decisions according to priming condition and stimulus onset asynchrony for Experiment 3. Each mean is based on 288 trials for one subject. (Results for ten additional subjects obtained over the SOA-range -160 to +240 msec are shown in Figure A4.18 below.)

rates between the incongruent and neutral conditions appear substantially more marked than between the neutral and congruent priming conditions. Significant differences in error rate were found for SOAs of 80 msec (χ^2 = 36.41), 160 msec (χ^2 = 36.80), and 320 msec (χ^2 = 10.55). With the exception of the maxima obtained with incongruent primes it appears from Figure 4.18 that error rates exhibit a slight general decline from an average of 0.12 at -480 msec to 0.11 at +480 msec.

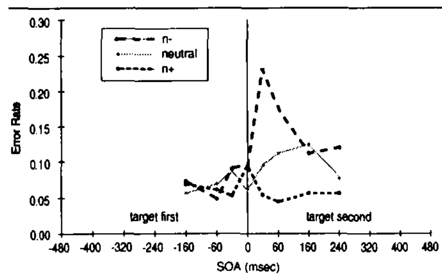


FIGURE A4.18. ERRORS: As for Figure 4.18; the variation of error rate for ten additional subjects obtained over the SOA-range -160 to +240 msec. (See Appendix 3 for further details.)

Additional-Subject Data

As with the first two experiments results were obtained for ten additional subjects over the restricted SOA range -160 to 240 msec. An increase in response latency accompanied by a lower error rate for the additional-

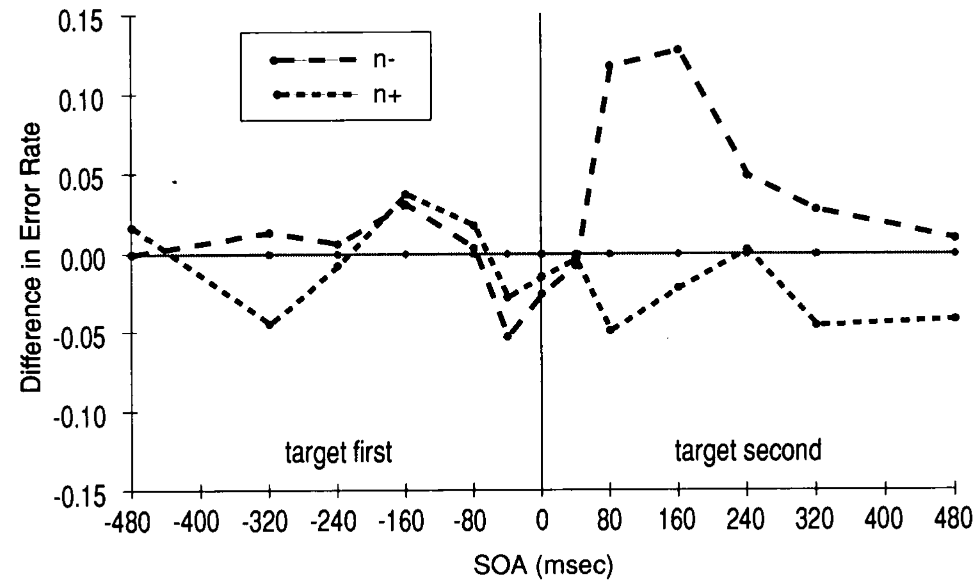


FIGURE 4.19. ERRORS: The difference in error rates for congruent and incongruent priming in relation to neutral priming as a function of prime-target stimulus onset asynchrony for Experiment 3. (Results for ten additional subjects obtained over the SOA-range -160 to +240 msec are shown in Figure A4.19 below.)

subject data in comparison to that for the main subject was obtained as with the earlier experiments; overall case-decision response times averaged 483.2 msec, just less than 107 msec in excess of the main-subject data. The overall error rate was 0.098. This compares with a figure of 0.117 for the main subject. From Figures A4.16 to A4.19 it appears that the priming effects obtained with the additional subjects were generally similar to those obtained for the main subject. However some differences are apparent: there is no discernable facilitation with

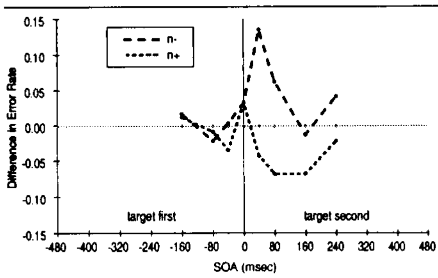


FIGURE A4.19. ERROR RATES: As for Figure 4.19; the difference in error rates in relation to neutral priming for ten additional subjects over the SOA-range -160 to +240 msec. (See Appendix 3 for further details.)

congruent primes for SOAs of 80 msec. This compares with the trend apparent in Figure 4.17 (Page 188) for the main subject. Since this latter trend was non-significant, though, this difference in main- and additional-subject data is not considered to be one of substance. However a contrast between main- and additional-subject data was obtained with error rates at 40 msec SOA. While Figure 4.19 shows that no differential priming effects were obtained with the main subject the reverse was found for the additional subjects ($\chi^2 = 36.88$, $p<.05$).

All ten additional subjects considered the word 'ether' to be no more suggestive of upper-case letters than to lower-case letters. Detailed results for additional subjects are given in Appendix 3.

DISCUSSION

In general the case-decision response times obtained were similar in magnitude to those for Experiment 1 for priming conditions of equivalent congruency. Albeit with caution this may suggest a degree of consistency with regard to absolute response times between experiments, and if compared with the response times for Experiment 2 further suggests that case-decision requires less time than name-decision.

The finding that significant name-priming effects were obtained throughout the greater part of the positive SOA range is of interest insofar as cross-attribute effects based upon typographic case are obtainable. Apart from the details relating to the time-course and the magnitude of any facilitatory or inhibitory effects this paradigm provides yet another example of a contextual effect that is characteristic of Stroop research. If, as before, it is assumed that the word 'ether' provides an effectively neutral priming condition then it follows that both significant facilitatory and inhibitory effects have been obtained for positive SOAs of 80 msec and above.

A comparison of the magnitude of the present facilitatory and inhibitory effects with those obtained in Experiment 1 is of interest in regard to both encoding and responding processes. Although there are dangers in comparing magnitudes across experiments some accounting for the findings can nevertheless be ventured.

That the magnitude of facilitatory priming effects in the present experiment (9.7 msec) is on average very slightly less than the magnitude of those for Experiment 1 (11.1 msec) suggests that the strength of cross-attribute facilitatory priming may also be slightly less than the strength of within-attribute facilitatory priming. (A similar comparison may also be made with additional-subject data.) An obvious problem when considering the priming effects of the present experiment, though, is the possibility that cross-attribute effects may have interacted unpredictably with the unavoidable within-attribute effects. If the within-attribute effects balance out across priming conditions then the smaller cross-attribute effect may be readily accounted for within the sensory-semantic model by the notion of the 'focal code' put forward by Nelson et al. (1977). Here it is assumed that encoding can be selectively directed; with the present experiment this would mean that as name information is a task-unrelated stimulus attribute its influence on case-decision latency would be attenuated. Interpreting Paivio's dual-coding model is more difficult with regard to selectivity. It may be claimed that the effect of information communicated via referential links may be less influential than information encoded locally. Additionally Paivio's (1978) view that the representation of semantic information is derived from imagery can be taken to suggest that the system is image-biased and thus more responsive to case rather than to name-priming. A problem with this latter suggestion is that is does not accord with the relatively large priming effects obtained in Experiment 2 with both the main and additional subjects when name information primed name-decision.

So far it has been argued that the smaller facilitatory effects in comparison to inhibitory effects on response time for this experiment is suggestive of selective facilitatory priming effects. The corollary of this is that cross-attribute inhibitory priming is non-selective. If the selective effect is an encoding rather than a responding phenomenon then this comparison suggests that inhibitory effects do not occur at the encoding stage. This supposition may also be considered in relation to the finding that the facilitatory effects (9.7 msec) are on average less than those for the inhibitory effects (12.3 msec) in the present experiment, a similar comparison holding for additional-subject data. However it should be pointed out that the inhibitory effects obtained in Experiment 1 (10.35 msec) were less than those for the present experiment. Although, as before, comparisons of the relative priming effects across experiments is problematic the results leave open the possibility that selective inhibition may occur with cross-attribute priming and that the same mechanisms may underlie both inhibitory and facilitatory effects. That is, as suggested by the PDP models, encoding could be both facilitatory and inhibitory.

With regard to the time-course of results in the present experiment both inhibitory and facilitatory effects on response time appear to be absent at an SOA of +40 msec before increasing markedly within the next 40 msec to a level similar to that held for a greater part of the remaining positive SOA range. This time-course is of interest in that it does not appear to be consistent with Glaser and Dünglehoff's (1984) picture categorisation data where the effect of both word-primes and temporal precedence was considered weak. If the case-decision task is regarded as one which involves the categorisation of a relatively limiting example of a pictorial attribute then it can be argued that an equivalence exists between this experiment and that carried out by Glaser and Dünglehoff. The present data, then, not only suggest that significant word-priming effects are obtainable on case-decision but also that these effects are subject to the relative speed of processing of the priming and task attributes. This finding adds support to the proposal in Chapter 3 that Glaser and Dünglehoff only obtained a weak effect because the SOA range used was insufficient in view of the relatively large differences in word- and picture-categorisation times they obtained. Glaser and Dünglehoff's (1984) rejection of the relative-speed hypothesis was consistent with what were considered to be the weak priming effects that they obtained. The findings from the present experiment thus contrast with Glaser and Dünglehoff's in that they are in keeping with the relative speed hypothesis.

The time-course of cross-attribute priming effects is also of interest in relation to the single- and dual-coding structures for the processing of word and picture information. In comparison to the within-attribute priming effects obtained with the first two experiments there is a delay in the time-course of cross-attribute effects upon respose latency. This is in line with the earlier predictions for this experiment and although this finding alone does not favour either one of the encoding models it can at least be taken to support a feature that both models have in common; namely that at some stage verbal and nonverbal attributes of a stimulus appear to be processed separately. Additionally the relative-speed explanation is supported by the suggestion arising from the first two experiments that name-encoding requires slightly more time than case-encoding. If this is so then this can account for the delay in both facilitatory and inhibitory effects. It has already been noted that the time-course of the effects upon error rate differ for the main and additional subjects. While the time-course of main-subject error data matched that for response latencies the same was not true for additional-subject data. Here it was found that effects upon error rate preceded effects upon response latency (see Figures A4.17, Page 188 and A4.19, Page 191). One explanation for the latter findings is that the errors could have resulted from the name-content of the prime being responded to as if it was the case-content of the target. Since on some occasions the additional subjects might have lapsed into a name-decision routine mediation between name- and case- information would not be necessary. This contrasts with the mediation that is required when case- and name-information are linked so that cross-attribute effects are enabled thus accounting for the time-course differences for correct responses.

Although it could be claimed that a name-decisions prevailed when the intended task was one of case-decision this is unlikely in view of other aspects of the additional-subject data. For example, if responses were being made consistently to name-information of the primes then these would be relatively fast for both the prime-words 'upper' and 'lower' and would occur relatively early in the time-course as the name-information would not have to be converted into its case-equivalent. On this basis the relatively slow response times occurring relatively late in the time-course as evidenced from the incongruent priming condition shown in Figure A4.16 (Page 187) would not be expected.

By way of a final comment in relation of the results obtained in the experiments carried out so far it appears that the facilitatory and inhibitory effects obtained suggest that similar mechanisms are involved for both cross- and within-attribute priming. This is of interest in relation to the experimental traditions discussed in Chapter 3 where within-attribute priming was characterised by facilitation, and the emphasis on inhibitory effects characterised by Stroop research. In particular this is relevant to the suggestion that spurious effects may have arisen from the particular reading and naming task requirements used in many Stroop experiments.

The relative magnitude of the priming effects obtained is of interest in relation to the two types of encoding microstructure that have been discussed. The present results, however, are difficult to interpret, both in view of the difficulty in comparing the magnitude of priming effects across experiments and also because case-priming that was unavoidably included along with the name-priming. Before the implications relative priming effects can be further considered it is necessary to carry out a more comprehensive investigation where the priming effects of name and case information on a case-decision task can be more clearly delineated. This is attempted in Experiment 4.

EXPERIMENT 4: Case- and Name-Priming of Case-Decision

An aim of the current experiment is to investigate the combined effects of typographic case and word-name information on a case-decision task. For this purpose target random letter strings are to be primed with stimuli containing both name and case information occurring in varying combinations of congruency as exemplified in Table 4.6.

TABLE 4.6. The seven priming conditions used in Experiment 4. The abbreviated notation for each condition that is used in the text is given in brackets.

Condition	(Notation)	Prime	Example of Target
case-congruent/name-congruent	(c+n+)	UPPER	YGSRO
case-congruent/name-congruent	(c+n+)	lower	mkbav
case-congruent/name-neutral	(c+)	ETHER	NBFDE
case-congruent/name-neutral	(c+)	ether	cpliy
case-congruent/name-incongruent	(c+n-)	LOWER	TFDXA
case-congruent/name-incongruent	(c+n-)	upper	lprth
case-incongruent/name-congruent	(c-n+)	upper	IGTBU
case-incongruent/name-congruent	(c-n+)	LOWER	otsfa
case-incongruent/name-neutral	(c-)	ether	DLRTI
case-incongruent/name-neutral	(c-)	ETHER	yianl
case-incongruent/name-incongruent	(c-n-)	lower	AOGDN
case-incongruent/name-incongruent	(c-n-)	UPPER	reijf
neutral	(N)	-----	SREYT
neutral	(N)	-----	hwepm

PREDICTED PRIMING EFFECTS

From Experiments 1 and 3 it appears that both case- and name-priming information affect case-decision response latencies. As an analysis in terms of separate encoding and responding processes has been consistent with the results obtained so far this approach will be further pursued. In accordance with the predictions and the results obtained in Experiment 1 significant case-priming effects upon a case-decision task are expected only for positive SOAs. Since the predictions of the name-priming effects for Experiment 3 that were based on relative speed still hold for the name-priming component in the present experiment significant name-priming effects are again only expected for SOAs in the region of 80 msec and above. Within this framework of expected gross time-course effects the likely outcome of combined case- and name-priming is considered; firstly in relation to encoding processes, secondly in relation to responding processes and, finally, in terms of the resultant effects of encoding and responding. The predictions which follow are, of course, for SOAs in excess of 80 msec.

Encoding Processes: Case- and Name-Priming Effects Combined

From the experiments carried out so far the possibility remains that encoding mechanisms may produce either facilitatory effects only, or, both facilitatory and inhibitory effects. This applies to both case- and name-priming information. A central question concerns whether and if so to what extent such case- and name-priming effects are additive. Although a simple arithmetic addition rule linking priming input to the time required for a certain degree of target-encoding is not expected to apply it may be nevertheless be plausible that target-encoding may be faster if preceded with a prime carrying both congruent case and name information than with a prime which only carries name information. This may be argued from the 'microstructure' of the spreading-activation and PDP accounts of the mechanisms underlying encoding. The nodes postulated within these models are assumed to be capable of being activated to varying levels according to context; more activatory connections arising from a greater range of congruent contextual information raise the level of activation of those individual nodes concerned. In the PDP models already discussed a similar argument also applies to the level of inhibition of particular nodes, that is, the degree of inhibition is related to the degree of incongruency of contextual information. Although an additive rule may be applicable it may, however, not be of a simple linear nature. This may be appreciated, for example, in view of an inevitable limit to the number of inter-nodal connections and the level of activation or inhibition that may be obtained within any one system; eventually a saturation point will be reached where further input effects no change in the level of activation or inhibition.

For the purpose of rough prediction it will be assumed that the saturation level of nodes responsible for case representation may be sufficiently high so that the encoding system is responsive to differing degrees of information carried by singly- or doubly-congruent or by incongruent primes. Within this context a simple form of predictive model is one where name- and case-priming effects on encoding are additive according to linear rules. This rule has been adopted for the encoding predictions given in Figures 4.20 and 4.21 (Pages 201 & 202). However it is plausible that while congruent case input may not result in saturation it may account for a relatively large proportion of potentially available activation. In this situation it is likely that the effect of further congruent input arising from a different modality on encoding time for a subsequently presented target may be less pronounced.

Encoding Processes: Inter-Attribute Dominance Effects

Although it has been suggested that the combined priming effects resulting from case and name information may be additive the relative contributions of these attributes to any overall effect has not been considered. Whereas Carr, McCauley, Sperber and Parmelee (1982) argue that in a system characterised by a strong form of single-encoding, within-modality and cross-modality combinations of prime and target should produce equal facilitations, the sensory-semantic model of picture and word-encoding proposed by Nelson et al. (1977) allows for selective effects that may depend upon task requirements. These versions of the single-encoding model will be referred to as 'non-selective' and 'selective' respectively. The issue regarding the selectivity of encoding models has been difficult to resolve; in Chapter 4 it was pointed out that a number of factors including the use of naming tasks may largely account for the inconsistent results that have been obtained with regard to the cross-attribute facilitation effects that were discussed.

The issue of selectivity is relevant to the current experiment; in a selective model the effect of case-priming on a case-decision task may dominate over the effect of name-priming while with a non-selective model dominance effects would not be expected. The notion of the focal code that was discussed in the context of the last experiment suggests that selective properties may be attributed to the sensory semantic model. Selectivity may be assumed to apply regardless of the microstructure within the model; that is, to any spreading-activation models which are facilitatory-only in nature as well as the PDP models which are capable of producing both facilitatory and inhibitory priming effects. For example with case-decision a 'c-' prime would be expected to produce a greater inhibitory effect than a 'n-' prime in the same way that in the same task facilitation arising from 'c+' would exceed that from 'n+' priming. If the spreading-activation and PDP models are used as a basis for accounting for encoding at a microstructural level, together with the two main variations of selectivity pertaining to a central semantic model, then four major encoding options arise:

1) selective & facilitation-only
2) selective & facilitation and inhibition
3) non-selective & facilitation and inhibition
4) non-selective & facilitation-only

The predicted encoding effects arising from pre-exposed primes at SOAs well in excess of zero based on these models are summarised in Figures 4.20 and 4.21 and are expressed in the form of response latencies relative to a neutral priming condition. Although there is no reference to the exact relative magnitudes of these effects some rough quantitative rules have nevertheless been adopted for the purposes of illustration. Firstly, in spite of the possibility of the saturation effect outlined above, the effects of combined priming are shown according to simple linear

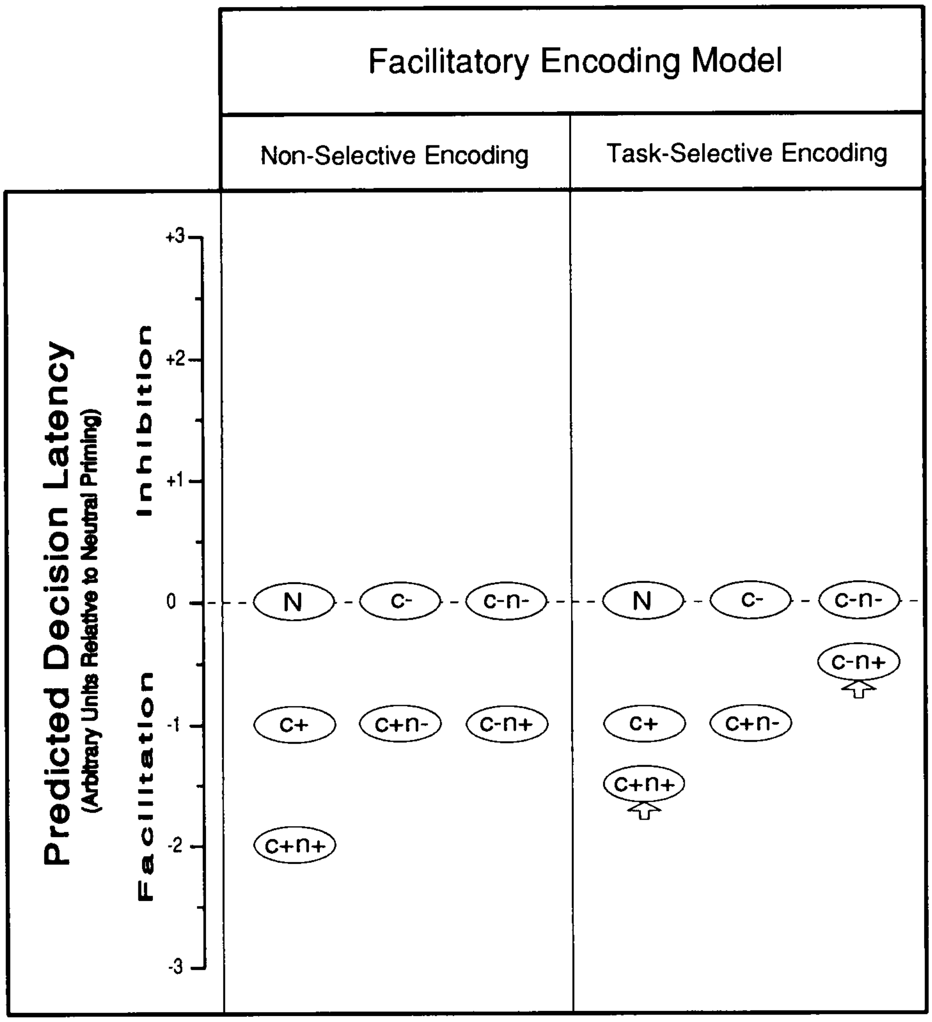


FIGURE 4.20: A schematic representation of the predicted effects of encoding processes upon case-decision latencies according to priming condition. The predictions are based on a model in which encoding processes are facilitatory. Additionally the selective and non-selective effects dependent upon the decision task are considered (see text). ('c' = case-priming, 'n' = name-priming, '+' = congruent priming, '-' = incongruent priming, 'N' = neutral priming, arrows indicate responding effects)

additive rules. Secondly, with the non-selective facilitatory-only encoding model (Figure 4.20) it is assumed that the change in case-decision response latency is the same both for congruent case and congruent name-priming. Furthermore, with a facilitatory and inhibitory encoding model the magnitude of the facilitatory effect for a congruent prime is assumed to be the same as the inhibitory effect for an incongruent prime. This latter assumption is derived from the similar but complementary facilitatory and inhibitory processes postulated in the

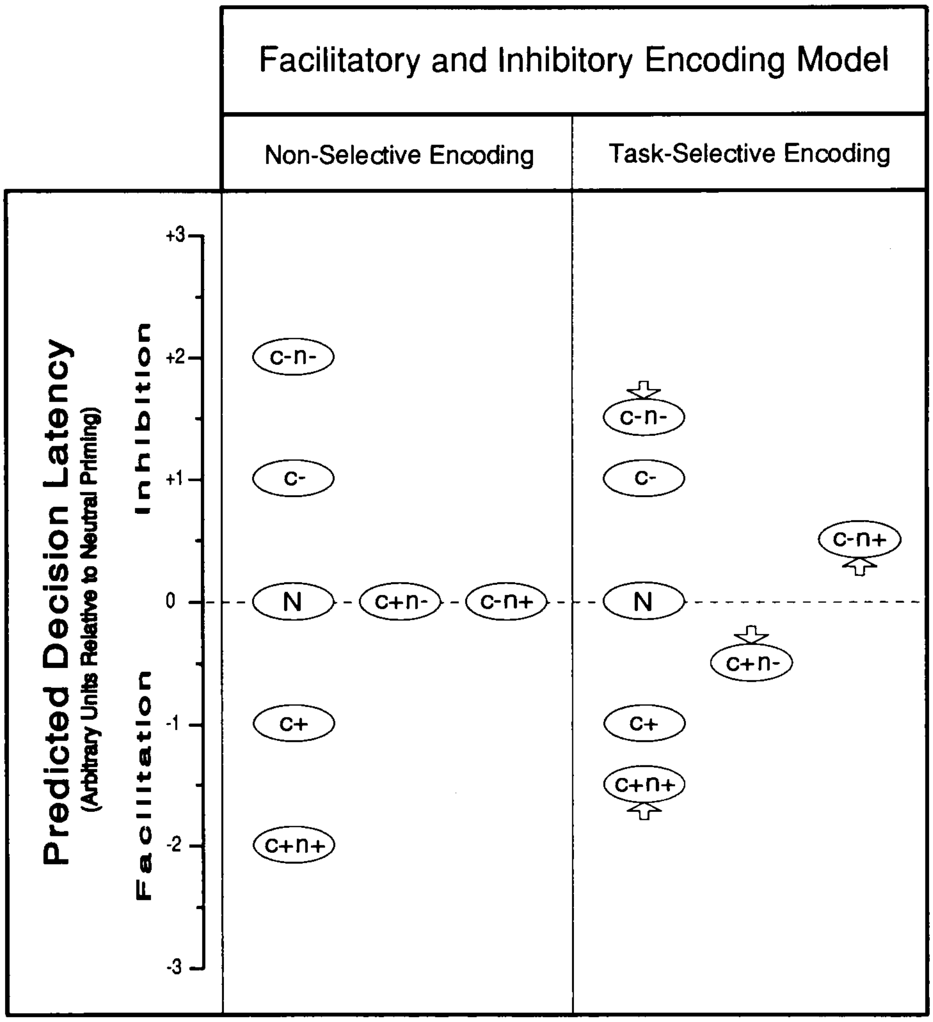


FIGURE 4.21. A schematic representation of the predicted effects of encoding processes upon case-decision latencies according to priming condition. The predictions are based on a model in which encoding processes are both facilitatory and inhibitory. Additionally the selective and non-selective effects dependent upon the decision task are considered (see text). ('c' = case-priming, 'n' = name-priming, '+' = congruent priming, '-' = incongruent priming, 'N' = neutral priming, arrows indicate responding effects)

PDP models discussed. On this basis in the facilitatory and inhibitory model the effects of case and name-priming information of alternate congruency with the target should cancel. This rule is implicit in the construction of Figure 4.21.

In the case of task-selective-encoding models it is more difficult to suggest a rough rule relating to the relative magnitudes of within-attribute and cross-attribute priming effects. Although a comparison of the relative response latencies in Experiments 1 and 3 (Figures 4.8 & 4.17, Pages 151 & 188) suggests that facilitatory case-priming effects on case-decision may be greater than name-priming effects on case-decision, this difference can only provide a rough indicator since the name-priming effects obtained in Experiment 3 may be confounded by case-priming effects. For convenience, and also so that the predicted effects of the selective and non-selective models are more readily distinguishable, in the figures below the change in case-decision response latency for name-priming has been made equal to half that for case-priming for a given congruency. This 'working figure' is applied to both facilitatory and inhibitory effects.

Responding Processes

Within responding mechanisms the basic question concerning the possible occurrence of facilitation and inhibition recurs. To deal with this, the argument from Taylor's (1977) data in Chapter 3 will be adopted in the way that it has been for Experiments 1 to 3. Briefly, the argument was that facilitatory priming effects result from stimulus processing rather than response processing. That is, factors at the response stage will be assumed to be responsible for inhibitory rather than facilitatory effects for both within- and cross-attribute priming.

The results of Experiments 1 and 3 do not rule out the possibility that both case- and name-priming can give rise to inhibitory effects at the responding stage with a case-decision task. If inhibitory responding effects are assumed then, as with encoding, two further questions arise. The first concerns whether the degree of inhibition arising from incongruent name-priming is the same as that from incongruent case-priming. The second question that arises concerns whether such inhibitory effects arising from different forms of incongruent information are additive. In an attempt to answer these questions it is necessary to go into further detail regarding responding mechanisms.

A mechanism that has been incorporated into response conflict accounts given by Morton (1969), Treisman (1969) and Neumann (1980) among others is a serial response buffer. In this context, response-competition can be interpreted in terms of access of competing motor programs to the response buffer which then becomes occupied. If a motor program which accesses the buffer is consistent with that for the response to a given target then the response is executed without delay. If, however, the program is inconsistent with that for a target then it has to be suppressed. With case-decision, for example, increased response latencies would result if the motor program for a right-hand key press had to be suppressed so that a left-hand response to the relevant target attribute could be effected.

If a responding mechanism characterised by a single-channel buffer is considered with reference to the question concerning inter-attribute dominance effects then it may be argued that the degree of inhibition resulting from the suppression of an unwanted motor program may be the same regardless of its source. This would be because inhibition depends upon the nature of the unwanted motor program rather than how it was invoked. In this situation the inhibitory effect of 'n-' and 'c-' priming components would be equal. A similar argument applies to the question concerning additivity of inhibitory priming effects. Since the same motor program would be activated with a 'c-' and a 'c-n-' prime the degree of suppression in favour of a correct response to a subsequently presented target would be the same in both instances so that additivity would not be expected. With the mixed congruency conditions 'c+n-' and 'c-n+' incongruent priming information would similarly elicit a respective motor program inconsistent with that required for an overt response. In this situation it would be expected that inhibitory responding effects would be obtained for both mixed priming conditions.

Resultant Effects

So far the nature of some processes that may occur within encoding and responding mechanisms have been considered. The resultant latencies are predicted, as before, in accordance with Taylor's (1977) assumption that encoding and responding processes act independently and serially. This simplifying assumption, which implies that the priming effects on encoding and responding may be additive, is again used only for the purposes of qualitative guidance rather than for strict quantitative prediction. To this end, the encoding predictions shown in Figures 4.20 and 4.21 (Pages 201 & 202) have been modified in accordance with the effects expected from a responding mechanism containing a single-channel response buffer. These resultant priming predictions are expressed in the form of the relative response latencies represented in Figures 4.22 to 4.25. The scaling units chosen, although arbitrary, are equivalent to those used in the predictions for Experiments 1 to 3. So that it is easier to see how modifications of the predicted encoding effects lead to the predicted resultant effects of encoding and responding processes, the left-hand panels of Figures 4.20 and 4.21 are repeated in the 'after encoding' panels of Figures 4.23 and 4.24. As before the representations are essentially schematic rather than quantitative.

Figure 4.22 shows the predictions for the resultant effects of encoding plus responding for the facilitatory-only and task-non-selective encoding model. Here it is assumed that any inhibitory effects that occur are due entirely to responding processes. Although the resultant effects are inevitably crudely represented there are nevertheless some notable features. In particular no difference in response latency is expected between the 'c-' and 'c-n-' priming conditions. This follows from the assumption that inhibitory responding effects are non-additive. It is also predicted that no difference in resultant effect should exist between the 'c+n-' and 'c-n+' conditions and, furthermore, the resultant response latency of these conditions should be coincident with the 'N' condition. Firstly this is in accordance with the assumption that encoding facilitation for congruent case and name information is equal in magnitude, and, that equal inhibitory effects result from incongruent name and case information at the responding stage. If the inhibitory

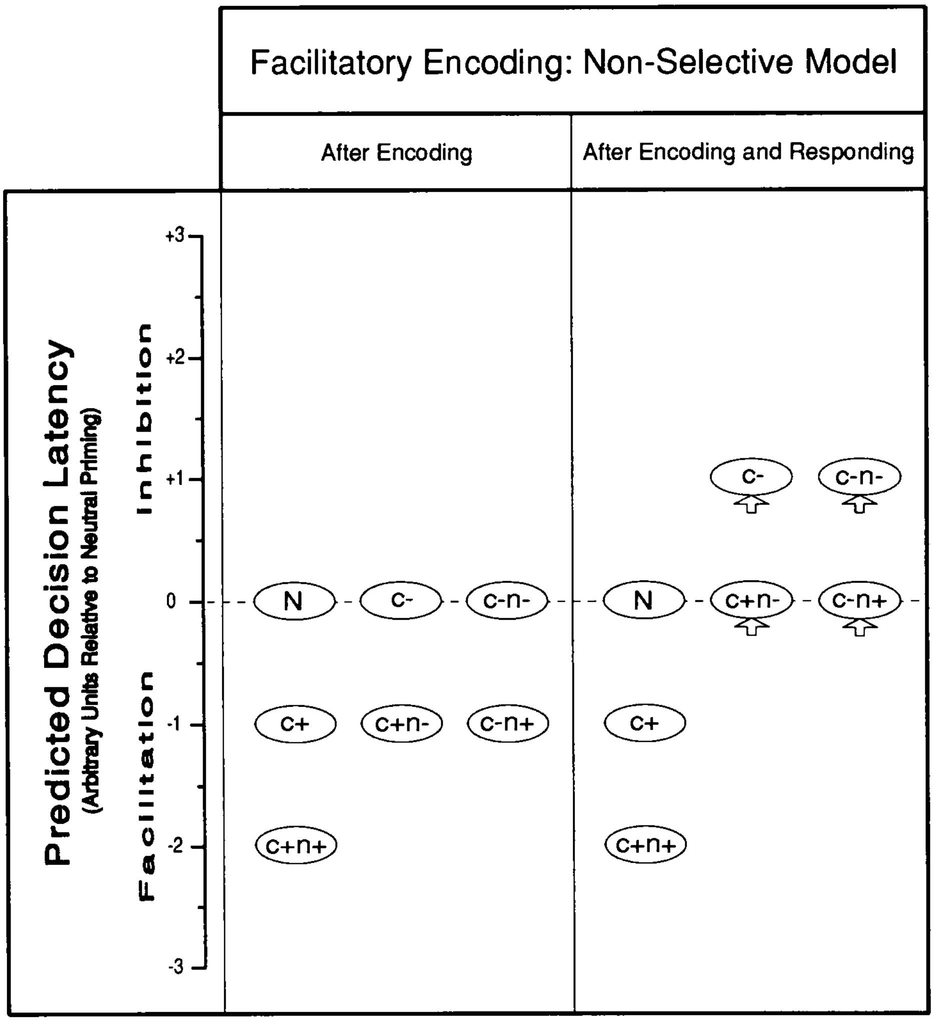


FIGURE 4.22. A schematic representation of the predicted effects of encoding and responding processes upon case-decision latencies according to priming condition. The predictions are based on a model in which encoding processes are facilitatory-only and task-non-selective (see text). ('c' = case-priming, 'n' = name-priming, '+' = congruent priming, '-' = incongruent priming, 'N' = neutral priming, arrows indicate responding effects)

effect arising from responding mechanisms is equal in magnitude to the facilitatory effect from encoding then coincidence with the 'N' condition follows.

The coincidence of 'c-' and 'c-n-' after encoding plus responding in Figure 4.23 for the facilitatory-only and task-selective encoding model is predictable for the same reasons as its task-non-selective counterpart (Figure 4.22). However the effect of task-selectivity results in a net

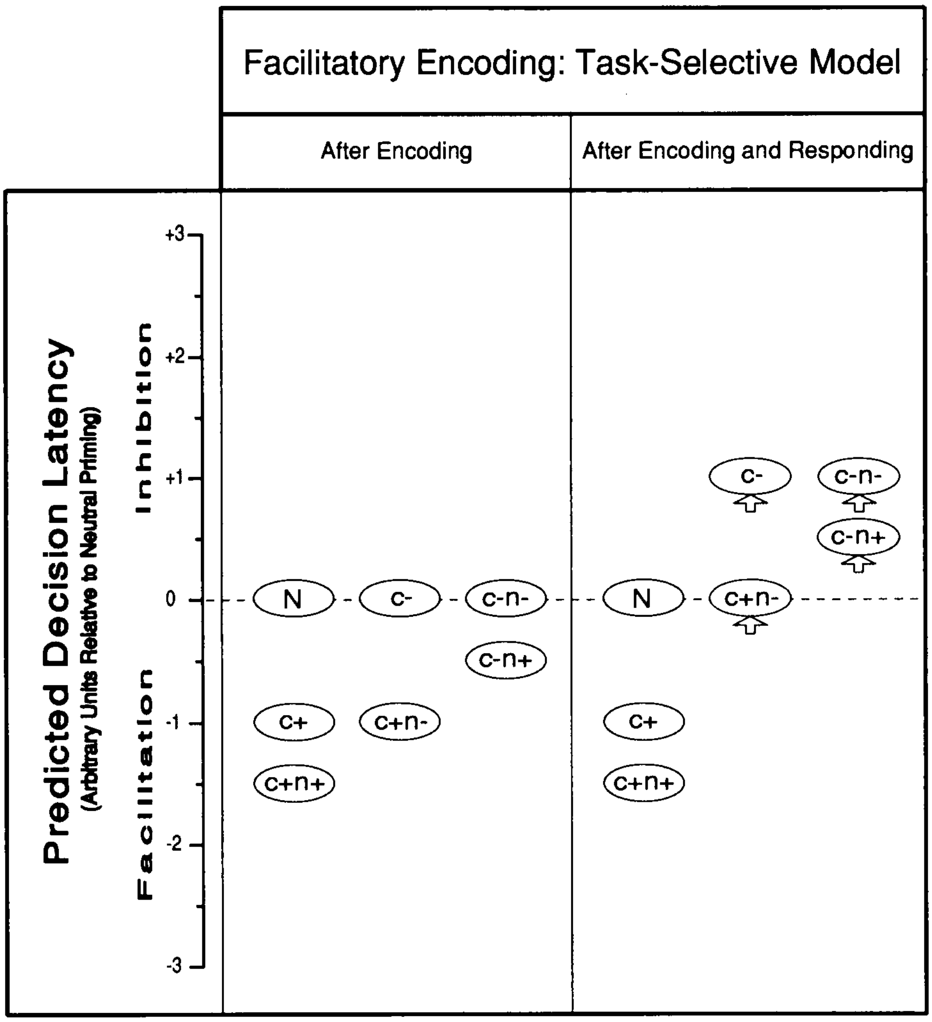


FIGURE 4.23. A schematic representation of the predicted effects of encoding and responding processes upon case-decision latencies according to priming condition. The predictions are based on a model in which encoding processes are facilitatory-only and task-selective (see text). ('c' = case-priming, 'n' = name-priming, '+' = congruent priming, '-' = incongruent priming, 'N' neutral priming, arrows indicate responding effects)

increase in response time for 'c-n+' in comparison to 'c+n-'. Again the coincidence of 'c+n-' with the 'N' condition follows from the assumption that the inhibitory effect arising from responding mechanisms is equal in magnitude to the facilitatory effect from encoding task-dependent information.

In Figures 4.24 and 4.25 predictions are based upon inhibitory effects that are due to encoding in addition to responding processes. Since inhibitory as well as facilitatory encoding effects are assumed to be

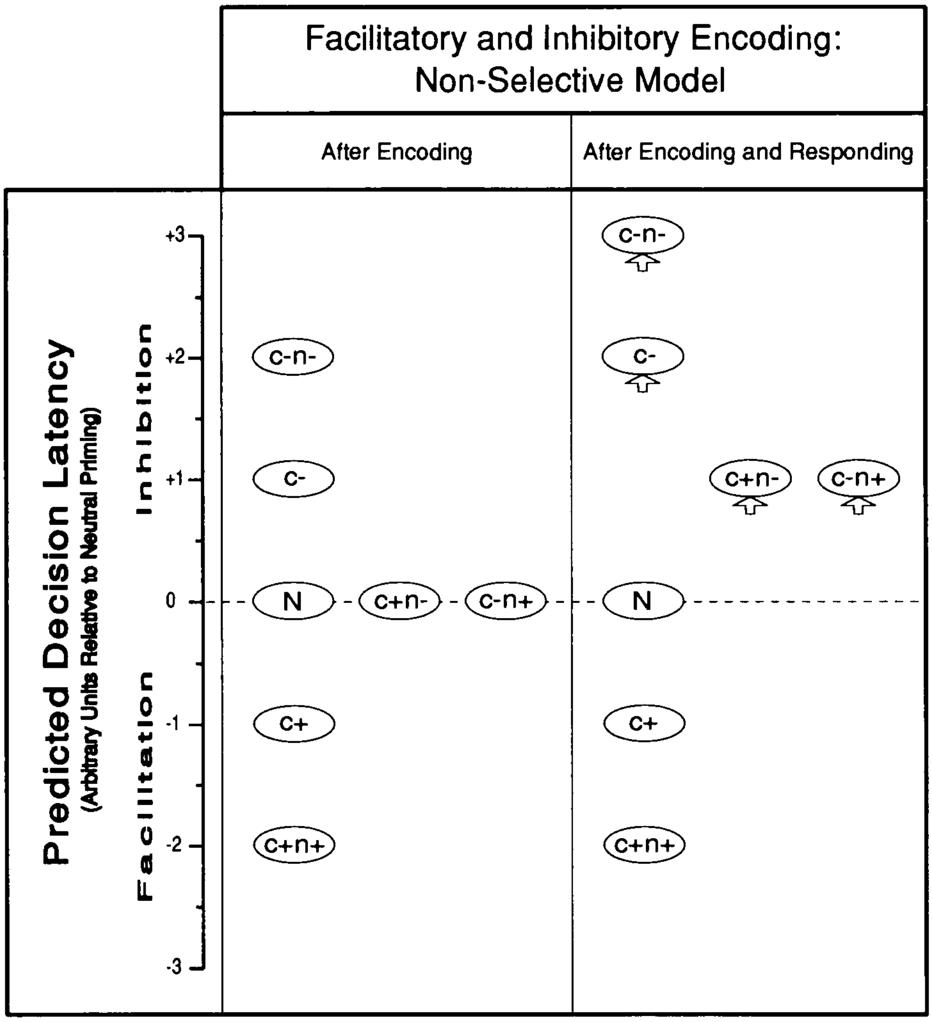


FIGURE 4.24. A schematic representation of the predicted effects of encoding and responding processes upon case-decision latencies according to priming condition. The predictions are based on a model in which encoding processes are facilitatory and inhibitory and task-non-selective (see text). ('c' = case-priming, 'n' = name-priming, '+' = congruent priming, '-' = incongruent priming, 'N' = neutral priming, arrows indicate responding effects)

additive a difference in latency between the 'c-' and 'c-n-' conditions is expected. This contrasts with the predictions for the facilitation-only encoding models. The only priming conditions expected be coincident in latency for facilitatory and inhibitory encoding models are 'c+n-' and 'c-n+' where task-non-selectivity is assumed. This, as with the facilitation-only model in Figure 4.22 (Page 206), is on account of the assumptions regarding encoding facilitation and inhibition being equal in magnitude and non-selective inhibitory responding effects.

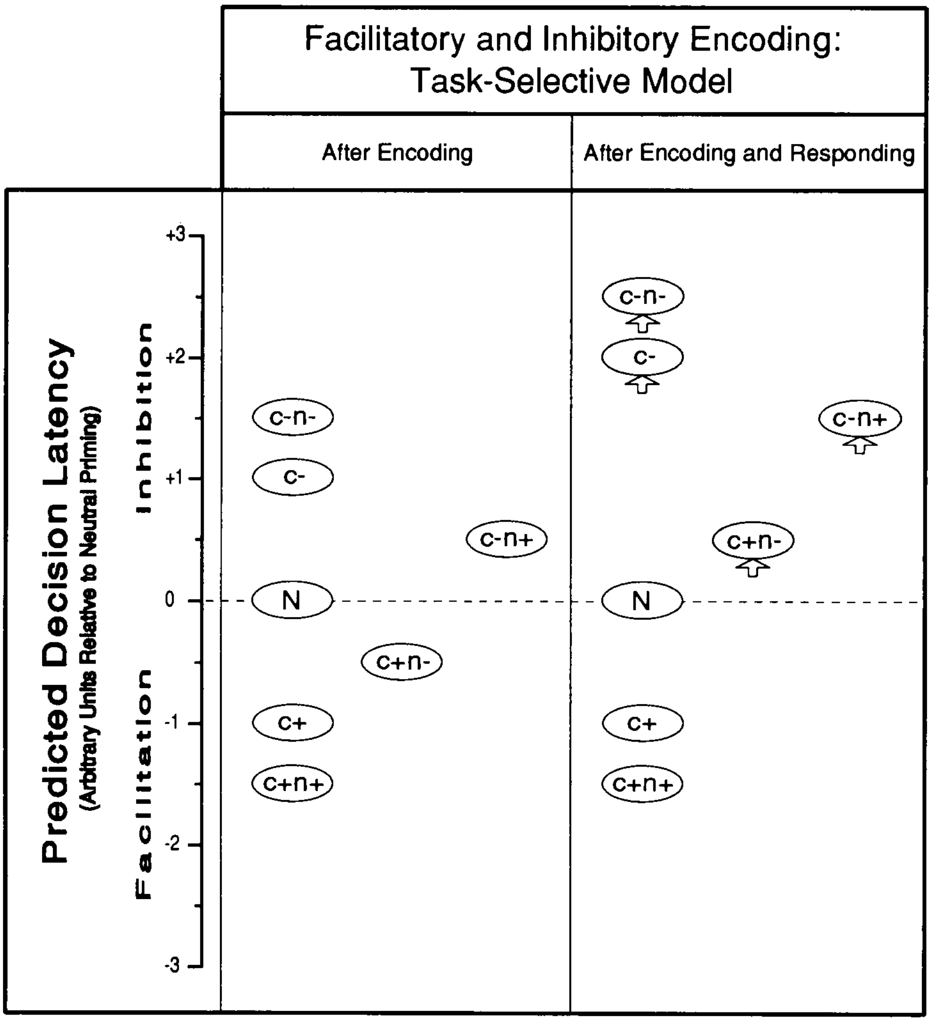


FIGURE 4.25. A schematic representation of the predicted effects of encoding and responding processes upon case decision latencies according to priming condition. The predictions are based on a model in which encoding processes are facilitatory and inhibitory and task-selective (see text). ('c' = case-priming, 'n' = name-priming, '+' = congruent priming, '-' = incongruent priming, 'N' = neutral priming, arrows indicate responding effects)

A comparison of the predictions in Figures 4.22 and 4.23 (Pages 206 and 207) draws attention to some response latency differences of a more general nature. For facilitatory-only encoding models the resultant facilitatory effects in comparison to the neutral condition are greater in magnitude than inhibitory effects. For facilitatory and inhibitory encoding models the resultant inhibitory effects are expected to exceed facilitatory effects in magnitude. Although the predictions of the resulting response latencies due to encoding and response processes are difficult to determine precisely the above characteristic patterns in relative magnitudes have nevertheless emerged. These predictions together with the predictions for the time-course of encoding and responding effects outlined earlier are now tested.

METHOD

Apparatus and Stimuli

The apparatus and the viewing conditions were the same as those used in Experiment 1. The stimuli were also of the same form and dimensions as the first experiment. A row of five dashes and the words 'upper', 'lower' and 'ether' formed the set of items from which primes were drawn. Targets consisted of strings of five letters randomly chosen and sequenced. The words and letter strings forming primes and targets were printed entirely in lower-case or entirely in upper-case letters. The stimuli were arranged according to the seven priming conditions which have already been illustrated on Table 4.6 (Page 197). The conditions were sequenced quasi-randomly so that there was no excessive clustering of any one experimental condition. Experimental trials were in blocks of 140 and similarly created practice trials were in blocks of 28.

Procedure

The procedure followed the same form as that adopted in the previous experiments. Familiarity with the use of the words 'upper' and 'lower' to denote specific typographic case forms was initially checked by asking the subject to categorise verbally a list of letter strings similar to those to be used as targets in the experimental trials. The list comprised ten upper-case and ten lower-case strings arranged randomly in terms of case and presented sequentially on the display monitor. The experiment was continued if at least eighteen of the twenty letter-strings were categorised correctly.

Subjects were asked to categorise target stimuli in terms of case. Primes were presented before, simultaneously with or after the target and remained visible until the subject's response. The sequence of events comprising a single trial was identical in form to that used in the previous experiments and is shown in Figures 4.6a to 4.6c (Page 148). As before 1500 msec elapsed between trials. The occurrence of an upper-case target letter string was registered by pressing a right-hand response key while a left-hand response key was used for the lower-case strings. Reaction times were measured from the onset of the target and only those falling within a 200 to 1000 msec range were accepted for analysis.

The session began with the block of 28 practice trials, the SOA being set at the value to be used in the first experimental block. Practice trials were run until a suitable balance between speed and accuracy was attained; i.e., a criterion of at least 80% accuracy for mean response times of 700 msec or less. As with the previous experiments SOAs of -480, -320, -240, -160, -80, -40, 0, 40, 80, 160, 240, 320, and 480 msec were used. The SOA was held constant within each block of trials but was altered randomly between blocks, each SOA value being used for two blocks. Each block of experimental trials took between five and ten minutes to complete with intervening rest periods of approximately three minutes. An experimental session lasted some two hours. At the end of a session the subject was asked (in the form of a leading question) to say whether the word 'ether' which was occasionally visible was more similar to the word 'upper' or the word 'lower' and whether the dashes were more similar to upper- or lower-case letters and the responses were noted. Experimental sessions were repeated so that a total of twelve sets of results were obtained.

RESULTS

Out of a total of 27,300 case-decision responses 17 fell beyond the allotted 200 to 1000 msec interval. Two out of the 17 outlying responses were shorter than 200 msec and were due to false starts while insufficient pressure on a response key or minor lapses in attention accounted for the remainder. The 17 outliers were not considered in any further analyses including the compilation of error scores.

Response Latencies

Significant priming effects were obtained; Mean correct case-decision time varied according to priming condition ($F(6,24591) = 51.05$, $p<.001$). The main effect for SOA was also significant, $F(12,24591) = 106.72$, $p<.001$. This variation with SOA would be expected in view of the discussion of the general effect upon response time due to such factors as psychological refractivity. The interaction between SOA and congruency across the entire SOA range was also significant, $F(72,24591) = 5.83$, $p<.001$. Again this would be expected as a result of the onset of differential priming effects in the zero SOA region.

As in Experiments 1 to 3 the data were examined in terms of prime-target order. For pre-exposed primes (ranging from +40 to +480 msec SOA) an SOA by Congruency ANOVA indicated significant case- or case-and-name-priming effects, $F(6,11350) = 120.73$, $p<.001$ while no significant effects were obtained for post-exposed primes (-480 to -40 msec SOA), $F(6,11388) = 0.57$, $p>.001$. Interaction between SOA and congruency was significant for pre-exposed primes, $F(30,11350) = 2.13$, $p<.001$, but non-significant for post-exposed primes, $F(30,11388) =$

0.69, p>.001. From these figures it appears that the differential priming effects with SOA detected by the interaction in the ANOVA for the entire SOA range would have occurred predominantly between -40 and +40 msec SOA. However while case- and name-priming effects do not vary differentially with congruency over the SOA ranges -480 to -40 the same is not true between +40 and +480 msec. The significant interaction effect obtained for SOAs above 40 msec may have arisen from delayed effects of name-priming as with Experiment 3. In the above respects the results so far appear to be consistent with those of the earlier experiments.

The mean correct case-decision response times for each SOA level for each of the seven priming conditions are represented in Figure 4.26. Difference values, as with the earlier experiments, were obtained by subtracting the means for the case-congruent and case-incongruent priming conditions from the means for the neutral condition. These differences in response time are shown in Figure 4.27 with the terms 'inhibition' and 'facilitation' referring to positive negative differences respectively. As before the SOA of the prime and target was measured in relation to the onset of the target so that positive SOA values indicate prime pre-exposures while negative SOAs show prime post-exposures.

As with the earlier experiments no significant differences were found in response latency between any of the priming conditions over the SOA range -480 to 0 msec. For the positive SOA range a reliable pattern of case- and name-priming effects is evident from inspection of Figures 4.26 and 4.27. As in the previous experiments a series of one-way ANOVAs was carried out across congruency conditions for each SOA and followed by the use of the Newman-Keuls method when a significant (p<.05) congruency effect was obtained for a given SOA. These tests confirmed the significance or non-significance of those effects (p<.05) readily apparent from the graphs. The additive effects of name- and case-priming were significant for case-congruent primes as indicated by the reliable differences in response time shown in

Figure 4.26. This observation was also supported by a further application of the Newman-Keuls method to the data collapsed over the positive SOA range. This yielded Q(11385)=6.2, p<.05 for name-congruent priming and Q(11385)=5.1, p<.05 for name-incongruent priming with

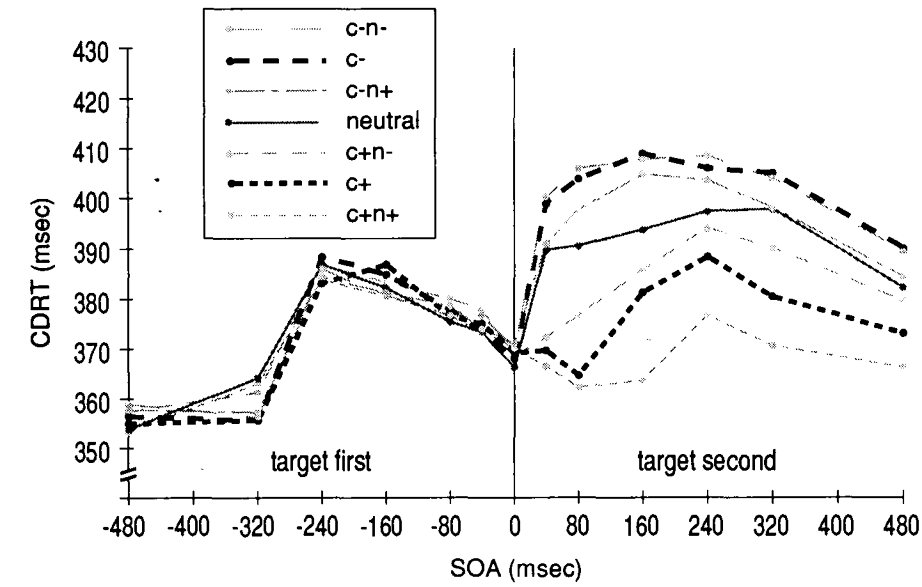


FIGURE 4.26. RESPONSE TIMES: Mean response times for correct case-decisions as a function of priming condition and prime-target stimulus onset asynchrony for Experiment 4. Each mean is based on 300 trials for one subject. (Results for additional subjects obtained over the SOA-range -160 to +240 msec are shown in Figure A4.26 below.)

case-congruent primes. However while significant differences were detected between the c- and c-n+ priming conditions, Q(11385)=4.1, p<.05 the same was not true with the c- and c-n- conditions, Q(11385)=0.2, p>.05.

In addition to the time-course of the differences in response latency as shown in Figure 4.27 the figures for the relative magnitude of the priming effects on response latency averaged over the +80 to +480 msec

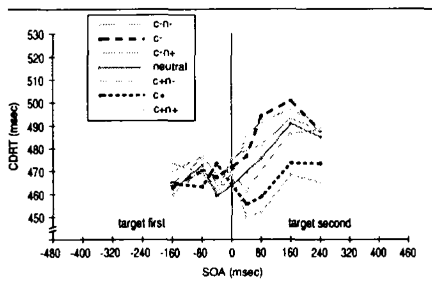


FIGURE A4.26. RESPONSE TIMES: As for Figure 4.26; mean correct case-decision response times for fourteen additional subjects over the SOA-range -160 to +240 msec. Each mean is based on 280 trials. (See Appendix 3 for further details.)

range are shown schematically in Figure 4.28. In relation to the neutral condition case-congruent-priming effects average some 15 msec while case-incongruency effects average approximately 9 msec. With case-congruent primes the additive effect of congruent name-priming was

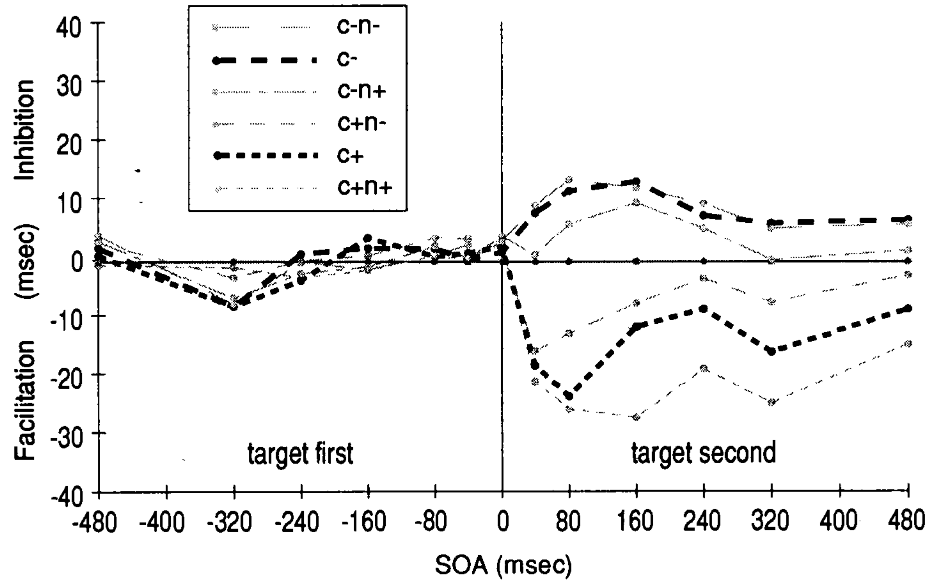


FIGURE 4.27. RESPONSE TIMES: The difference in mean case-decision response times for congruent and incongruent priming in relation to neutral priming as a function of prime-target stimulus onset asynchrony for Experiment 4. (Results for additional subjects obtained over the SOA-range -160 to +240 msec are shown in Figure A4.27 below.)

very nearly 9.5 msec while with case-incongruent primes congruent name-priming resulted in a drop of nearly 5.1 msec in response latency. The asymmetry between the additive effects of incongruent name-priming for case-congruent primes (7.70 msec) and case-incongruent primes (0.15 msec) is also shown in the diagram.

The onset of case- and name-priming effects has so far been collectively reported within the positive SOA range. However some more detailed

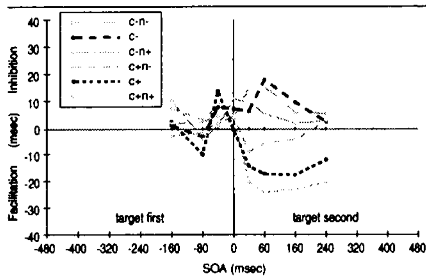


FIGURE A4.27. RESPONSE TIMES: As for Figure 4.27; The difference in mean response times in relation to neutral priming for fourteen additional subjects over the SOA-range -160 to +240 msec. (See Appendix 3 for further details.)

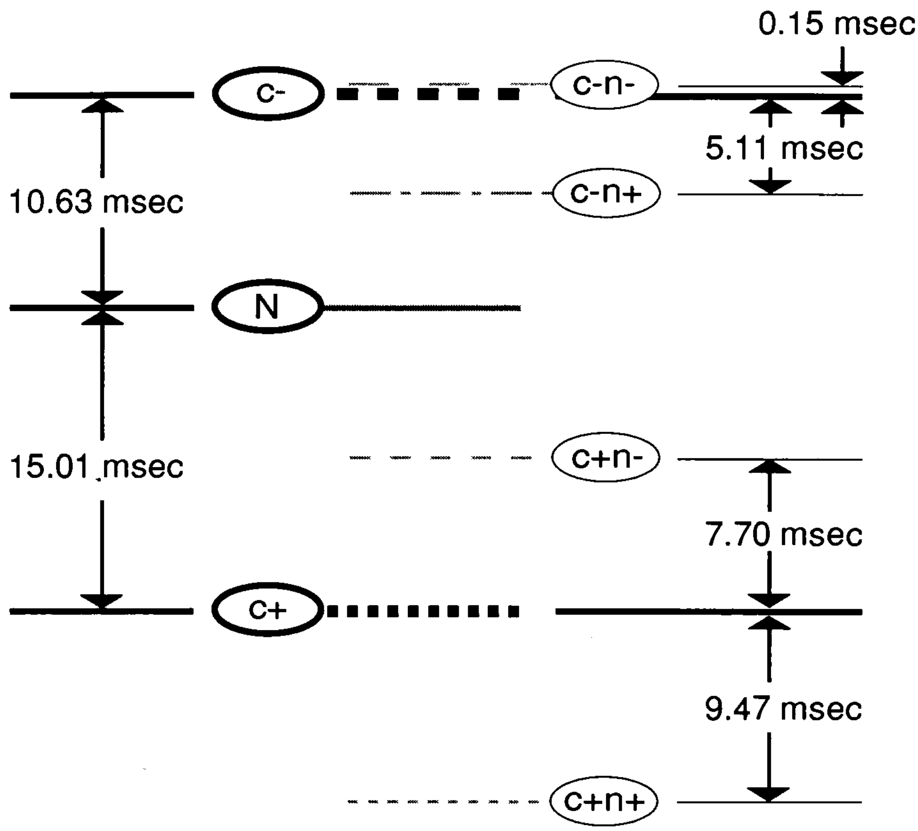


FIGURE 4.28. A schematic representation of the relative differences in mean case-decision response times for congruent and incongruent priming averaged over the +80 to +480 msec SOA range for Experiment 4. Each mean is based on 1500 trials for one subject. (Results for additional subjects over the SOA-range 80 to 240 msec are shown in Figure A4.28 below.)

observations may be made from both Figure 4.27 and the re-presentation of the name-priming effects in relation to the case-only priming conditions shown in Figures 4.29 and 4.30. While, for case-congruency, name-incongruent effects become established at 80 msec SOA

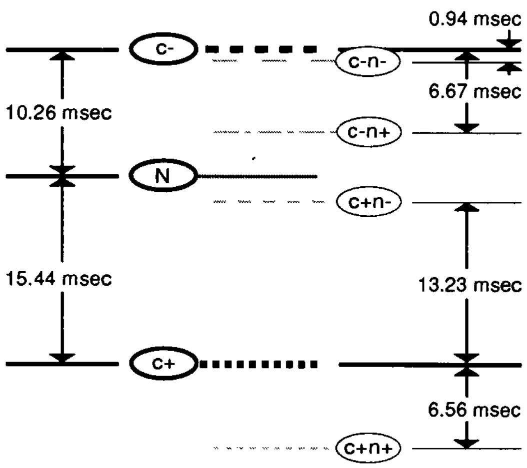


FIGURE A4.28. As for Figure 4.28; A schematic representation of the relative differences in mean case-decision response times for congruent and incongruent priming averaged over the +80 to +240 msec SOA range for the fourteen additional subjects used in Experiment 4. Each mean is based on 840 trials. (See Appendix 3 for further details.)

(Q,1861=3.9, p<.05) name-congruent effects develop more slowly; remaining non-significant at 80 msec SOA (Q,1861=0.8 p>.05) and becoming significant at 160 msec SOA (Q,1885=4.7, p<.05). In this respect the results shown in Figure 4.29 closely resemble the name-

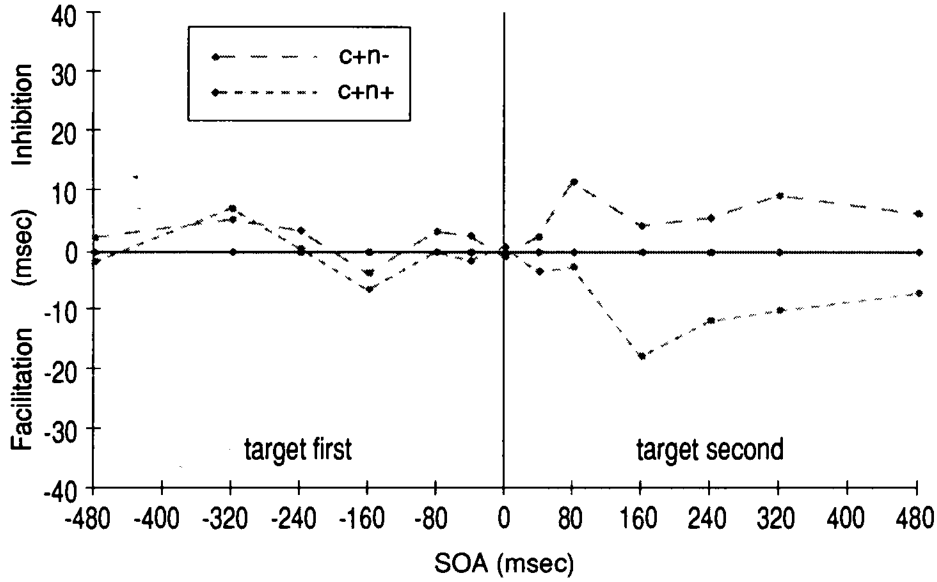


FIGURE 4.29. RESPONSE TIMES: The difference in mean case-decision response times for name-congruent and name-incongruent primes in relation to the respective case-congruent priming condition as a function of prime-target stimulus onset asynchrony for Experiment 4. (Results for additional subjects obtained over the SOA-range -160 to +240 msec are shown in Figure A4.29 below.)

priming of case-decision results shown for the last experiment in Figure 4.17 (Page 188). The time-course in Figure 4.29 is distinctly different from that of Figure 4.30. Although this is mainly due to the absence of name-incongruent priming it may also be observed that significant name-congruent effects are obtained by the time that an onset asynchrony of 40 msec is reached (Q,1800=2.8, p<.05).

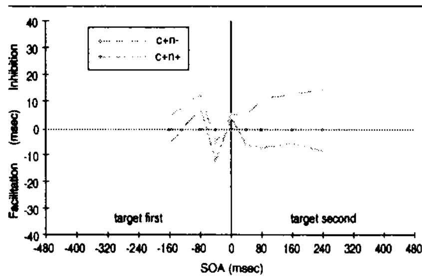


FIGURE A4.29. RESPONSE TIMES: As for Figure 4.29; The difference in mean response times in relation to case-congruent priming for fourteen additional subjects over the SOA-range -160 to +240 msec. (See Appendix 3 for further details.)

The variation of response time with SOA (rather than the variation of the relative priming effects) may also be considered, as with the earlier experiments. As before it is assumed that any systematic variation of carry-over effects from one SOA value to another is minimal. On this basis it can be seen from Figure 4.26 that a minimum disruptive effect on

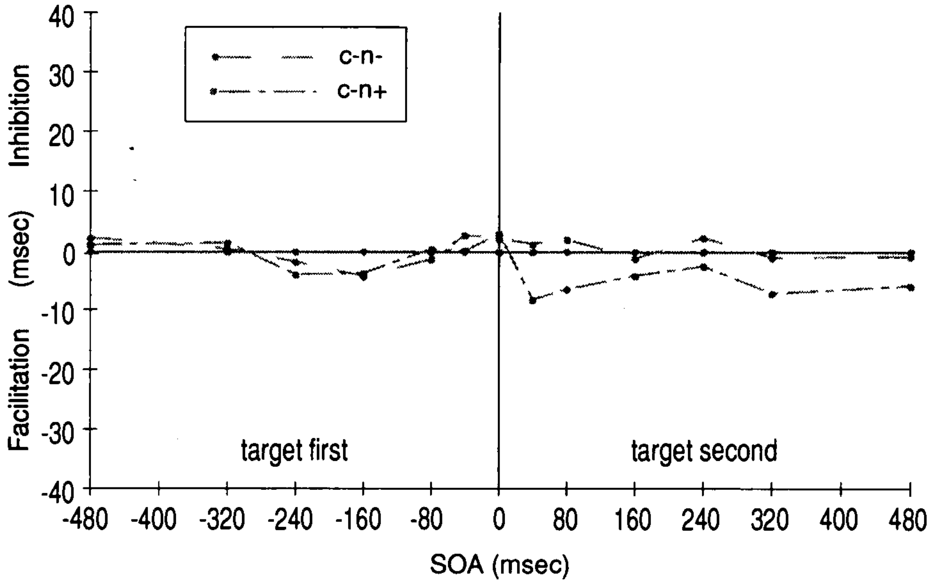


FIGURE 4.30. RESPONSE TIMES: The difference in mean case-decision response times for name-congruent and name-incongruent primes in relation to the respective case-incongruent priming condition as a function of prime-target stimulus onset asynchrony for Experiment 4. (Results for additional subjects obtained over the SOA-range -160 to +240 msec are shown in Figure A4.30 below.)

response latency was obtained for SOA of -480 and -320 msec. The subjective observation that very few primes were visible at -480 msec SOA value is corroborated by the obtained mean response time across priming conditions of 356.2 msec, SD=46.4. Although most primes would have been visible at -320 msec SOA the relatively low response times may, at least, be partly accounted for by a number of trial-

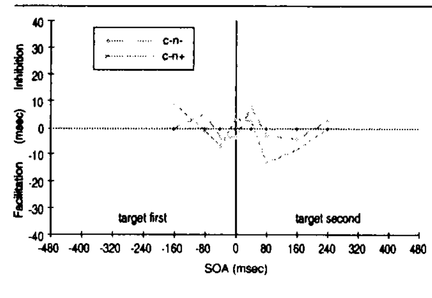


FIGURE A4.30. RESPONSE TIMES: As for Figure 4.30; The difference in mean response times in relation to case-incongruent priming for fourteen additional subjects over the SOA-range -160 to +240 msec. (See Appendix 3 for further details.)

terminating responses occurring before the onset of the prime. Response latencies increased from 359.2 to 385.9 msec over the SOA range -320 to -240 msec and then decreased uniformly to 369.3 msec at zero SOA. As SOA values increased above zero the response latencies for all priming conditions also generally increased as is evident from Figure 4.26.

Overall the case-decision reaction times obtained in the present experiment averaged 379.8 msec. This is very nearly equal to the average of 379.6 msec obtained in the first experiment and, furthermore, similar to the overall time of 376.6 msec obtained in Experiment 3. These figures may again be compared with the overall name-decision reaction times for Experiment 2 which averaged 391.2 msec. As before, however, the above cross-experimental comparisons are made with caution.

Error Rates

The error rates for each priming condition are shown in Figure 4.31 as a proportion of the total responses for each condition at each SOA level. In view of difficulties that may arise when attempting to identify trends in error rate for each priming condition from the composite graph, the error data are further represented in Figures 4.32 to 4.34. Figure 4.32 shows the error rates for the congruent and incongruent priming conditions in comparison to the neutral condition while Figures 4.33 and 4.34 show the error variations for name-priming in relation to the c+ and c- priming conditions respectively. The statistical significance of the overall effects of name- and case-priming upon error rate was assessed by a series of Chi-square tests carried out for each SOA. The results of these tests are reported when relevant to discussion and when the significance or non-significance may not be obvious.

As before the pattern of differences in error rates between the priming conditions has some similarity to the pattern of response latencies. From Figure 4.32 it appears that reliable trends in the time-course of priming effects were only obtained when primes preceded the targets; at zero

SOA $\chi^2=11.9$, $p>.05$ while $\chi^2=131.6$, $p<.05$ and 100.7, $p<.05$ for SOAs of 40 and 80 msec respectively. Although the differences in error rates for the 160, 240 and 320 msec SOAs were less marked they nevertheless remained significant; $\chi^2=37.9$, 20.2, $p<.05$ and 23.5, $p<.05$ respectively.

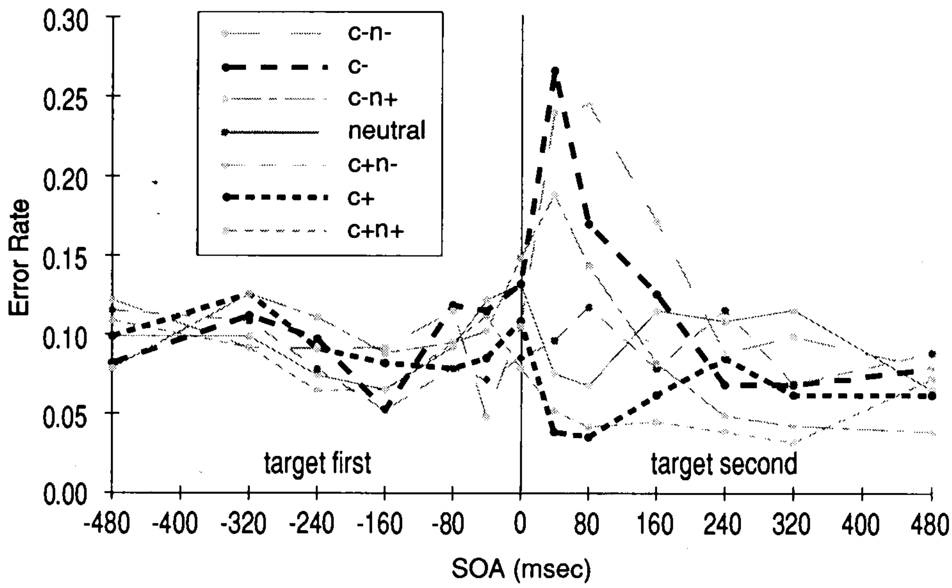


FIGURE 4.31. ERRORS: The variation in error rate for case-decisions according to priming condition and stimulus onset asynchrony for Experiment 4. Each mean is based on 300 trials for one subject. (Results for additional subjects obtained over the SOA-range -160 to +240 msec are shown in Figure A4.31 below.)

At 480 msec SOA significant differences in error rate were not obtained; $\chi^2=7.1$, $p>.05$. For the shorter positive SOA values the difference in error rates between the neutral and case-incongruent conditions is substantially more marked than for neutral and case-congruent priming. With the exception of the maxima obtained with case-incongruent primes it appears from Figure 4.31 that error rates exhibit a general decline from an average of 0.102 at -480 msec to 0.071 at +480 msec.

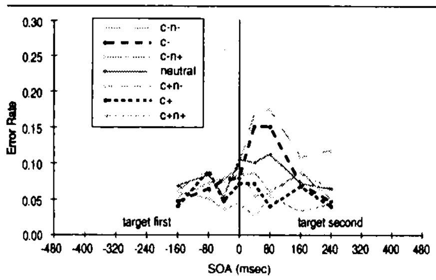


FIGURE A4.31. ERRORS: As for Figure 4.31; the variation of error rate for fourteen additional subjects obtained over the SOA-range -160 to +240 msec. (See Appendix 3 for further details.)

A further noticeable feature of the error scores is that the sharp increase in the +80 msec SOA region was only common to incongruent case primes. Primes with an incongruent name component did not produce relatively high error rates unless accompanied by incongruent case

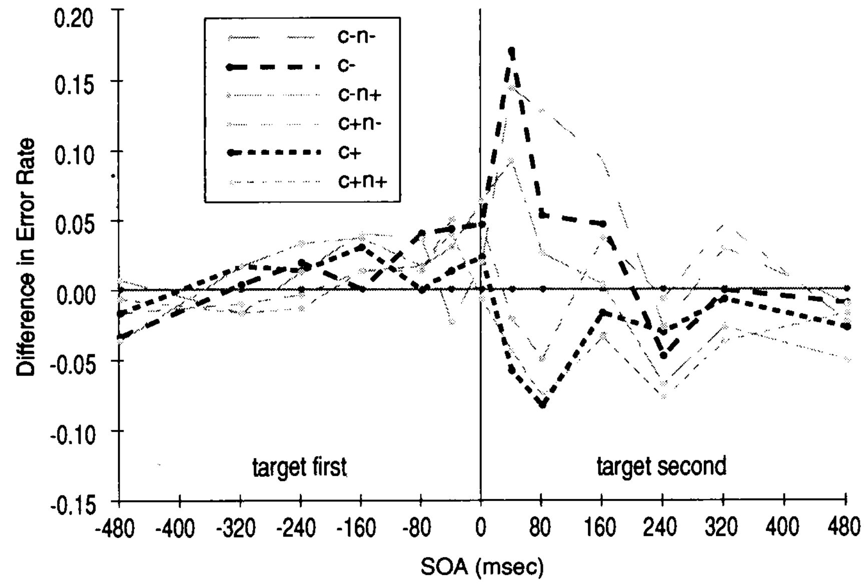


FIGURE 4.32. ERRORS: The difference in error rates for congruent and incongruent priming in relation to neutral priming as a function of prime-target stimulus onset asynchrony for Experiment 4. (Results for additional subjects obtained over the SOA-range -160 to +240 msec are shown in Figure A4.32 below.)

information. name-priming, however, does appear to have an effect on error rates as indicated by the trends apparent in Figures 4.33 and 4.34. Here additive effects may be detected throughout a greater portion of the positive SOA range.

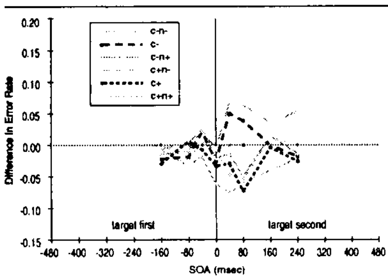


FIGURE A4.32. ERROR RATES: As for Figure 4.32; the difference in error rates in relation to neutral priming for fourteen additional subjects over the SOA-range -160 to +240 msec. (See Appendix 3 for further details.)

Additional-Subject Data

As with the earlier experiments results were obtained for fourteen additional subjects over the restricted SOA range -160 to 240 msec. Again an increase in case decision response latency was accompanied by

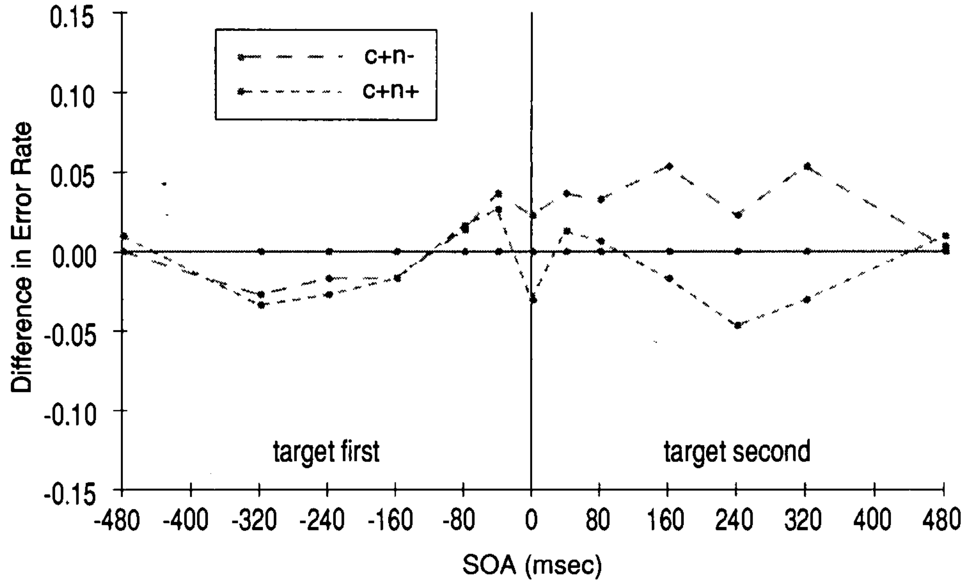


FIGURE 4.33. ERRORS: The difference in error rates for name-congruent and name-incongruent primes in relation to the case-congruent priming condition as a function of prime-target stimulus onset asynchrony for Experiment 4. (Results for additional subjects obtained over the SOA-range -160 to +240 msec are shown in Figure A4.33 below.)

a lower error rate for the additional-subject data in comparison to that for the main subject; overall response times averaged 471.9 msec, almost 92 msec in excess of the main-subject data. The overall error rate was 0.080. This compares with a figure of 0.107 for the main subject.

The priming effects obtained with the additional subjects were in general similar to those obtained for the main subject; this is apparent from Figures A4.26 to A4.34. However it should be noted that while

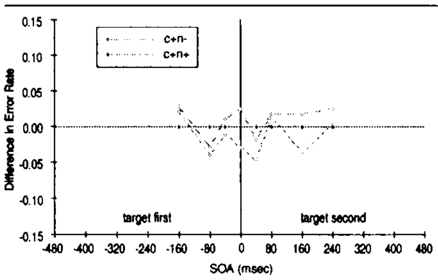


FIGURE A4.33. ERROR RATES: As for Figure 4.33; the difference in error rates in relation to neutral priming for fourteen additional subjects over the SOA-range -160 to +240 msec. (See Appendix 3 for further details.)

significant name-priming effects were obtained with case-congruent primes for SOAs of 80 (Q,1770=3.4, p<.05), and 240 (Q,1827=4.0, p<.05) msec SOA, the apparent trends between the 'c+' and the respective 'c+n+' or 'c+n-'conditions in Figure A4.29 (Page 217) were

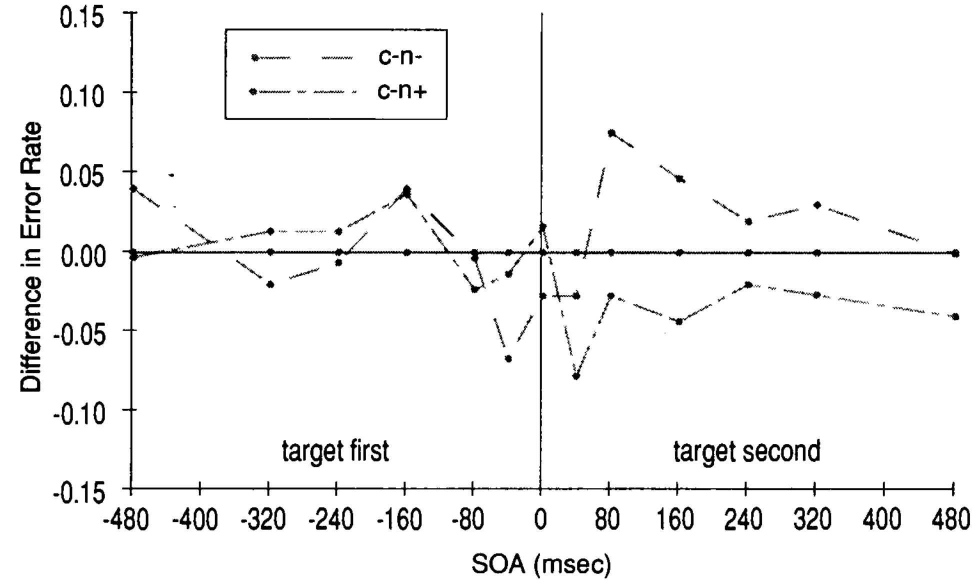


FIGURE 4.34. ERRORS: The difference in error rates for name-congruent and name-incongruent primes in relation to the case-incongruent priming condition as a function of prime-target stimulus onset asynchrony for Experiment 4. (Results for fourteen additional subjects obtained over the SOA-range -160 to +240 msec are shown in Figure A4.34 below.)

not significant. Similarly trends in congruent name-priming with case-incongruent primes that may be discernible in Figure A4.29 (Page 218) were also found to be non-significant. The differences here between the main- and additional-subject data are, however, minor.

Apart from some perturbations the overall pattern of error data with main and additional subjects was similar; again the interested reader is referred to Appendix 3 for further details.

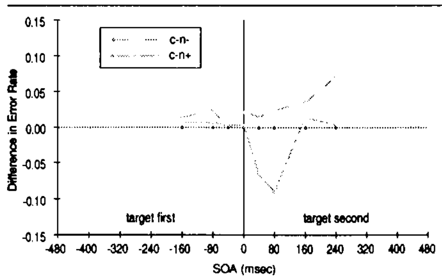


FIGURE A4.34. ERROR RATES: As for Figure 4.34; the difference in error rates in relation to neutral priming for fourteen additional subjects over the SOA-range -160 to +240 msec. (See Appendix 3 for further details.)

In response to a leading question regarding which of the two typographic cases the horizontal bars more closely resembled the answer from each of the additional subjects was to the effect that it was neither one nor the other. A similar response was obtained relating to a leading question regarding which of the two typographic case-denoting names the word 'ether' more closely represented.

DISCUSSION

General Effect of the Presence of a Prime

As with the previous experiments the presence of a prime, regardless of the specific information it may convey, appeared to have a general slowing effect upon response latency. Also, as before, a negative correlation between response speed and error rate was apparent. To this end variations in latency for post-exposed primes may be at least partly accountable by a speed-accuracy tradeoff as argued in Experiment 1. In the context of the discussions of the earlier experiments the present results do not appear to offer any further insights into the general effect of a prime upon a case-decision task.

The additional finding with the main-subject data in the present experiment that case-decision response latencies were similar in duration to those obtained in Experiments 1 and 3 points to the consistency of the magnitude of response latencies for a given stimulus attribute across experiments. (Although a similar cross-experimental comparison of response times with the additional subjects is problematical the present results are also not inconsistent with the earlier experiments.) This in turn lends further support to the earlier arguments where a relative speed hypothesis was used to account for the delay in the effect of name-priming in comparison to case-priming on case-decision latencies.

Time-Course of Congruency Effects

The time-course of results for case-priming is consistent with the results obtained in Experiment 1, that is, case-priming effects were obtained for all positive SOAs. The present results are also consistent with those from Experiment 3 insofar that the obtained name-incongruent priming effects were significant by the time a +80 msec onset asynchrony was reached. Likewise, a name-congruent priming effect was obtained for case-congruent primes by +160 msec onset asynchrony. However, unlike the last experiment name-congruent priming was obtained at +40 msec for the main subject. This was facilitatory only and obtained with case-incongruent primes. The discrepancy between this result and that for Experiment 3 could be explained by a name-congruent priming effect with case-incongruent primes being masked at +40 msec by a non-significant effect obtained with case-congruent primes. This relative delay in facilitatory name-priming for case-congruent primes in relation to case-incongruent primes may be accounted for in terms of relative speed of processing in that encoding of name input may require a few tens of milliseconds over that required for case input. In view of this it is possible that the speeded processing of case-congruent primes by some 15 msec allows less time for the name component to take effect than with the more slowly processed case-incongruent primes. A similar argument could also apply regarding the availability of encoded name input to responding mechanisms: the additional facilitating effect of congruent name information with case-congruent primes has less time to take effect than when case facilitation does not take place. This may account for the asymmetry in the onset of congruent and incongruent name-priming obtained in the present experiment (Figure 4.29, Page 217) and in Experiment 3 (Figure 4.17, Page 188).

Facilitation and Inhibition

The case-priming effects obtained for SOAs of 40 msec and above can be regarded as facilitatory and inhibitory if, as before, it is assumed that the row of minus signs provided an effectively neutral priming condition. The occurrence of case facilitation and inhibition is consistent with Experiment 1. To some extent there is also a consistency with the present results for name-priming of case-decisions and those of Experiment 3. If, as before, the word 'ether' is regarded as neutral in terms of name-priming then it follows that significant facilitatory name-priming effects were obtained when combined with both case-congruent and case-incongruent primes. The situation regarding inhibitory name-priming effects is, however, slightly different; the relative effects that were obtained with case-congruent primes were not apparent in conjunction with case-incongruency. This disparity emerges as a result of the resolution of the case- and name-priming components that is afforded by the present experiment. Clearly an aggregate of the name-priming effects collapsed across the two case-priming alternatives would bring the present results into line with those obtained in Experiment 3.

If, upon the occurrence of a prime, subjects generated a set of expected targets then, if a target consistent with the prime was expected, the response to this could be speeded and that for an inconsistent target slowed. Although congruent and incongruent prime-target pairs occurred with equal probability subjects may nevertheless have generated an expected target set for reasons such as congruent relationships being noticed and remembered. On this basis facilitation would be predictable for case-consistent primes, and, it is possible that further facilitation could arise when case and name information were congruent. A similar argument is applicable to incongruent information leading to the obtained inhibitory effects (e.g., Posner & Snyder, 1975; Neely, 1977). However facilitation and inhibition would be likely to occur later rather than earlier in the time-course of SOAs if strategic priming effects are assumed to be relatively slow acting. For example, Posner & Snyder (1975) obtained inhibition, which they attributed to strategic effects, at prime-target intervals of 300 msec and above. In view of this, automatic effects in relation to possible mechanisms involved with encoding, decision and responding processes are now considered, the assumption being that processing follows a series of independent stages with input being encoded prior to decision making and response generation.

With encoding, facilitation of case-decisions with congruent case priming can be accounted for in terms of the level of activation of the respective case-form representation being raised. Similarly, if it is assumed that interconnections exist between representations of case and name information then it is also possible that any relative increase in level of activation obtained with congruent case and name input would be reflected in the magnitude of priming effects obtained. An assumption relating to the models involving spreading activation was that the level of activation depended upon the number of activatory connections. In turn the number of these connections was assumed to depend upon contextual information. On this basis, for example, congruent name and congruent case information would be expected to produce greater facilitation than congruent case information alone and the present results are consistent with this. If similar and complementary processes occur with inhibition as for facilitation (Rumelhart & McClelland, 1981) then inhibitory effects would be expected to follow a pattern similar to facilitatory effects. However, while increased facilitation resulted from combined congruent case and name primes, inhibition with combined incongruent primes was no greater than with incongruent case information alone. Here, within-attribute inhibition could have occurred in the absence of cross-attribute inhibition. Alternatively, and consistent with other spreading activation accounts (e.g., Posner & Snyder, 1975), is the possibility that while within- and cross-attribute facilitation could occur during encoding inhibition does not occur at all.

With decision making the function may be regarded as at least twofold; firstly, to make a decision regarding whether an input has occurred which meets the requirements of a predetermined task and, secondly, to initiate an appropriate response. If case-decisions were based upon comparisons against a stored set of representations relating to the task then one assumption is that this set could contain case rather than name information. Initial stages of decision making could then be subject to facilitation if the case attribute of a prime activated its representation within a task set and speeded comparison of consistent target information. Similarly, inhibition could result for such reasons as activation of one element of a task set resulting in the inhibition of other elements, or, inconsistent information having a threshold raising effect. In terms of the above mechanism case priming rather than name priming effects would be expected. While this could account for no relative increase in inhibition for target incongruent name and case information combined, there is clearly a difficulty with the relative inhibition found with incongruent name priming in conjunction with congruent case primes. However, name priming effects could have occurred if, in addition to the case representations, associated name information was held along with, or was accessible from, the task set. This could account for the relative increase in facilitation with congruent name primes, and, the relative inhibition with incongruent name priming combined with congruent case priming. As with encoding, though, if levels of activation vary according to an aggregate of within- and cross-attribute information, it is difficult to account for no relative increase in inhibition with incongruent case and name priming. Similarly, if responses could be pre-programmed on the occurrence of a prime and if these are subject to varying levels of activation then the degree of facilitation or inhibition could depend as before upon the overall consistency of prime and target information.

Another possible account for facilitation is if responses proceeded on the basis of prime information alone, thus giving rise to an early start with consistent targets. In this case, however, the magnitude of facilitation might be expected to reflect the prime-target onset asynchrony and increase with larger positive SOAs. Since this did not occur it is unlikely that facilitation over the greater part of the SOA range can be accounted for in this way. It follows that information distinguishing a prime from a target could be used in processes leading to an execution of a response.

The present results can also be considered in terms of response competition. Here it is assumed that potential responses are generated for primes as well as targets and that these compete for access to a limited capacity output buffer. With consistent prime and target information identical response programs would be generated and one possibility is that these could be treated as a single response released on occurrence of the target. In this case it would be expected that target responses would be neither impeded nor facilitated. A further possibility, however, is that facilitation could arise as a result of mutual priming with compatible responses on access to, or, within the buffer. On this basis the effect of compatible case and name primes on case-response latencies could be greater than the effect of compatible case priming alone. Here though, the order in which responses become available may be an important factor; this is now considered also with reference to inconsistent responses.

It has been noted that inhibition could result from competition for a limited capacity response channel if potential responses to primes inconsistent with targets were available first and had to be suppressed. With regard to pre-exposed combined primes, if it is assumed that responses to case information are generated in less time than those for name information, then a series of two potential responses could precede the target response. With combined target-inconsistent case and name primes one possibility is that each response is suppressed in turn before the arrival of the target response. However, this might require more time than suppression of a single response from case-only priming and, hence, it is difficult on this basis to explain the lack of a relative inhibitory effect between the above two conditions. Alternatively, with combined inhibitory priming, the first two responses (consistent with each other) could act as a singular response, in this sense making the combined condition equivalent to the case-only condition. With combined incongruent case and congruent name information, inhibition could still arise as the initial case-response would have to be suppressed before the remaining target-consistent responses arrive. With this latter condition relative facilitation in comparison to case-incongruent priming could have arisen from mutual priming between the consecutive name and target responses, or, from other mechanisms. However, if facilitation was entirely due to mutual priming between consecutive responses then this would not explain the overall facilitation obtained with combined case-congruent and name-incongruent primes. The relative inhibitory effect of name-incongruent information when combined with case-congruent primes, however, may be accounted for by response competition since an inconsistent response to name information would precede the target response. Again, the overall facilitation in comparison to the neutral condition could have arisen from other mechanisms.

A further possibility is that response competition could result from only the response immediately prior to the target response having to be suppressed. This would be consistent with inhibition for combined case- and name-incongruent primes being similar to case-incongruent primes, and, would also account for the relative inhibitory effect obtained with name-incongruent information in conjunction with case-congruent information. Here, though, other mechanisms would be responsible for the overall facilitation obtained with combined case-congruent and name-incongruent primes. With combined incongruent case and congruent name primes, however, the obtained overall inhibition would not be expected. Apart from other possible sources of inhibition, this latter result suggests that response competition could arise from a target-inconsistent response to a prime, but, without it having to be consecutive with the target response. It may be noted that the difference in error rates between case-incongruent and combined case and name-incongruent conditions suggested in Figure 4.33 (Page 222) may not be inconsistent with the latter arguments. The probability of occurrence of an unwanted response could increase as a result of the additional incongruent name input. The frequency in occurrence of incorrect responses, however, is not bound to vary in accordance with the latency of correct responses.

A further point can be made regarding response competition and the magnitude of facilitatory and inhibitory effects. If it is assumed that any facilitation or inhibition depends upon the nature of responses rather than how they were invoked then the magnitude of any case facilitation should be similar to that for name facilitation and, likewise, case inhibition should be similar to name inhibition. The inevitable combination of case information with name information in the present method, however, does not allow the magnitude of name priming to be directly obtained. Nevertheless, it can be noted from Figures 4.28 and A4.28 (Page 216) that whereas case-only facilitation was 15.01 msec (15.44 msec with additional subjects), when combined primes contained a congruent name component response latencies differed by 9.47 and 5.11 msec (6.56 and 6.67 msec with additional subjects) from their respective case-only conditions. These differences in facilitation were greater than the differences in inhibition: whereas case-only inhibition was 10.63 msec (10.26 msec for additional subjects) the difference in latencies resulting from a name-incongruent component was 7.70 msec (13.23 msec for additional subjects). Albeit with caution, a possible interpretation of this is that, when inhibitory effects occurred, they were subject to less variation than facilitatory effects. On this basis inhibitory effects could be argued to be consistent with similar time costs involved with suppression of responses, regardless of how they were generated. This applies less easily to facilitation. This interpretation, however, discounts other sources of inhibition and further assumes response competition effects do not interact with other priming effects.

From the above discussion different accounts of the combined priming effects remain viable. Although facilitation could arise from encoding, it could also arise from decision and response processes. While there are some difficulties in accounting for both facilitation and inhibition during encoding, response competition remains viable as an account for inhibitory effects. These results are further considered in the next chapter. Firstly, however, a remaining major priming possibility to be tested concerns the influence of case information upon name-decisions. This is of interest in relation to the earlier arguments concerning possible similarities in underlying mechanisms responsible for cross-attribute and within-attribute priming.

EXPERIMENT 5: Case-Priming of Name-decision

In this experiment the last remaining major priming possibility where case information is used to prime a name-decision task is investigated. As with Experiment 1 case-priming is effected through the use of strings consisting entirely of upper-case letters, or, entirely of lower-case letters. Also, as with the first experiment, effectively neutral priming is considered to be achievable through the use of a row of dashes. A binary name-decision task is possible if, as with Experiment 2, the words 'upper' and 'lower' are used as targets. The arrangement of stimuli used according to the congruency of the prime case with the target name is shown in Table 4.7. The expected similarities in priming effects between the present and the earlier experiments are detailed in the next section.

TABLE 4.7. Examples of the three priming conditions used in Experiment 5.

Condition	(Notation)	Example of Prime	Target
case-congruent	(c+)	HRWIH	upper
case-congruent	(c+)	eihrq	lower
case-incongruent	(c-)	hdpuw	upper
case-incongruent	(c-)	IBTUF	lower
neutral	(N)	-----	upper
neutral	(N)	-----	lower

PREDICTED PRIMING EFFECTS

It may be observed from Table 4.7 that an unavoidable problem with the stimuli used concerns the fact that unwanted case information is contained within the target. Since it has been assumed that case information is encoded in less time than name information it is likely in view of the processing models so far discussed that the unwanted case information will affect name-decision latencies if a relative-speed principle still holds. Although the effect of unwanted case information carried by the target may balance out across priming conditions there is the additional problem that it may mask any effects of the case information contained in the prime. In view of this predictions relating to likely trends in the magnitude of overall priming effects may be difficult to make. Additionally effects due to the case content of a prime may not be obtainable or readily detectable from the results. If, however, any case-priming effects are detectable their time-course should not be affected by the target's case content.

Encoding Effects

In view of the argument presented in Experiment 4 that encoding effects are facilitatory-only in nature the predictions of case-priming effects upon name-decision will be made on this basis. If the overall structure of encoding processes is arranged according to the single- or dual-coding models so far discussed then a link between the processing of word-name and case information is possible. On this basis it may be predicted that name-decision will be facilitated by primes which are case-congruent with the target name. In terms of the priming conditions specified in Table 4.7 the 'c+' latencies should be relatively shorter than the latencies for the 'N' condition. Encoding effects due to case-incongruent primes are not expected to occur if facilitatory-only encoding is assumed.

Responding Effects

If inhibition is due to response-competition then it is possible that case information carried by the prime which is incongruent with the target name will result in the initiation of a motor programme which will have to be suppressed if a correct response is to be effected. In accordance with the response-competition hypothesis it is thus expected that response latencies for the 'c-' condition will be relatively longer than those for the neutral condition. In this manner the inhibitory effects should be consistent with those obtained in the preceding experiments.

Predicted Time-Course of Encoding and Responding Effects

If facilitation is assumed to be due to encoding mechanisms and that priming effects may arise from completed or partially completed processing of previously presented case information then it may be assumed that such effects should be detectable for pre-exposed primes. Additionally, however, it may also be noted that the results of the previous experiments were taken to be indicative that case-encoding requires less time than name-encoding. In relation to the overall single- and dual-coding structures it is thus conceivable that the more rapidly processed case information from a simultaneously presented prime, or, a prime that follows within a few tens of milliseconds after the onset of the target, will available in time to affect slower name-encoding. In this situation facilitatory effects for the 'c+' condition may be expected at zero and, perhaps, at -40 msec SOA. However since the difference in response latencies for name-decisions and case-decisions was only in the order of 20 msec then it may be more reasonable to expect that while case-priming effects on name-decision may be detectable at SOAs of zero or greater they will not be detected for SOAs of -40 msec or below.

The early availability of encoded case information in comparison to encoded name information may also have implications for the time-course of inhibitory priming effects. If such effects are attributed to a single-channel responding system similar to that outlined in Experiment 4 then the early arrival of encoded case-priming information incongruent with that for a correct target response will trigger a motor program which will ultimately require suppression. On this basis if case information is encoded more rapidly than name information it is possible that inhibitory effects may also be obtained at zero SOA and, perhaps, at -40 msec SOA.

The effects of case information carried by the prime and target may be partly distinguishable from the time-course. In particular if facilitatory encoding effects decay with time then it is likely that with increasing SOA the masking effect of the target case will increase. Similarly it is possible that at very short positive SOA values the case-effects of the prime may dominate since a finite time would be required for the effects of the target case to become established. A difference in the time-course of inhibitory effects may not be so apparent in view of the finding from the previous experiments so far that inhibitory effects do not appear to diminish within the range of prime-target onset asynchronies used.

Summary

Apart from the confounding of prime and target case information, predictions of relative facilitatory and inhibitory effects may be made in accordance with encoding processes that are characterised by spreading-activation and response processes which are subject to inhibitory effects. While facilitatory and inhibitory effects may be predictable according to the assigned congruency of the priming conditions exemplified in Table 4.7 (Page 232) for SOAs of zero and above, these effects may be less clearly delineated at the larger SOAs because of the masking effect of target case information. On the basis that case-encoding is faster than name-encoding the predicted time-course is distinct from those in the previous experiments where no priming effects were predicted or detected at zero SOA. The above predictions are now tested.

METHOD

Apparatus and Stimuli

The apparatus and viewing conditions were identical to those used in Experiment 1. Stimuli were also of the same form and dimensions as Experiment 1. Random letter strings, a different string for each trial, were used for congruent and incongruent priming while a row of five dashes was used for the neutral condition. Targets consisted of the words 'upper' or 'lower'. Examples of the three experimental conditions used have been shown in Table 4.7 (Page 232). The conditions, as with the other experiments, were sequenced quasi-randomly so that there was no excessive clustering of any one experimental condition. Experimental trials were in blocks of 72 and similarly created practice trials were in blocks of 24.

Procedure

The procedure was largely identical to that adopted in Experiments 1 to 4. Familiarity with the use of the words 'upper' and 'lower' to denote specific typographic case forms was initially checked by asking the subject to categorise verbally a list of letter strings similar to those to be used as primes in the experimental trials. The list comprised ten upper-case and ten lower-case strings arranged randomly in terms of case and presented sequentially on the display monitor. The experiment was continued if at least eighteen of the twenty letter-strings were categorised correctly.

The sequence comprising a single trial depended upon whether the primes were presented simultaneously or before and after the targets as shown in Figures 4.6a to 4.6c (Page 148). Subjects were asked to respond according to word-name of the target that was level with the markers and not to respond to the letter-strings below the target. The occurrence of the word 'upper' was registered by pressing a right-hand response key while a left-hand response key was used for the word 'lower'. Reaction times were measured from the onset of the target and only those falling within a 200 to 1000 msec range were accepted for analysis.

The session began with a block of 24 practice trials with the SOA set at the value to be used in the first experimental block. Practice trials were run until a suitable balance between speed and accuracy was reached. As with the earlier Experiments the criterion was at least 80% accuracy for mean response times of 700 msec or less. SOAs of -480, -320, -240, -160, -80, -40, 0, 40, 80, 160, 240, 320, and 480 msec were used. The SOA was held constant within each block of trials but altered randomly between blocks, each SOA value being used for two blocks. A block of experimental trials took between five and ten minutes to complete and was separated by a rest period of approximately three minutes. An experimental session lasted approximately two hours. At the end of the session the subject was asked (in the form of a leading question) to say whether the horizontal bars which were occasionally visible were more similar to upper-case or lower-case letters and the response was noted. Experimental sessions were repeated so that a total of twelve sets of results were obtained.

RESULTS

Out of a total of 11,232 name-decision responses 7 fell beyond the allotted 200 to 1000 msec interval. Five out of the 7 outliers were shorter than 200 msec and were due to false starts while insufficient pressure on a response key or minor lapses in attention accounted for the remainder. The 7 outliers were not considered in any further analyses including the compilation of error scores.

Response Latencies

The effects of case-priming upon name-decision response time were significant; a 13 (SOA) by 3 (congruency) ANOVA yielded an $F(2,10146)$ of 16.29, $p<.001$. The effect of prime-target onset asynchrony on response latencies was also significant, $F(12,10146) = 71.56$, $p<.001$. Significant interaction effects between SOA and congruency were not obtained; $F(24,10146) = 1.50$, $p>.001$.

The above data were examined in terms of prime-target order. Significant case-priming effects for pre-exposed and simultaneously presented primes were indicated by a further SOA by Congruency ANOVA carried out across the SOA range 0 to +480 msec, F(2,5449) =

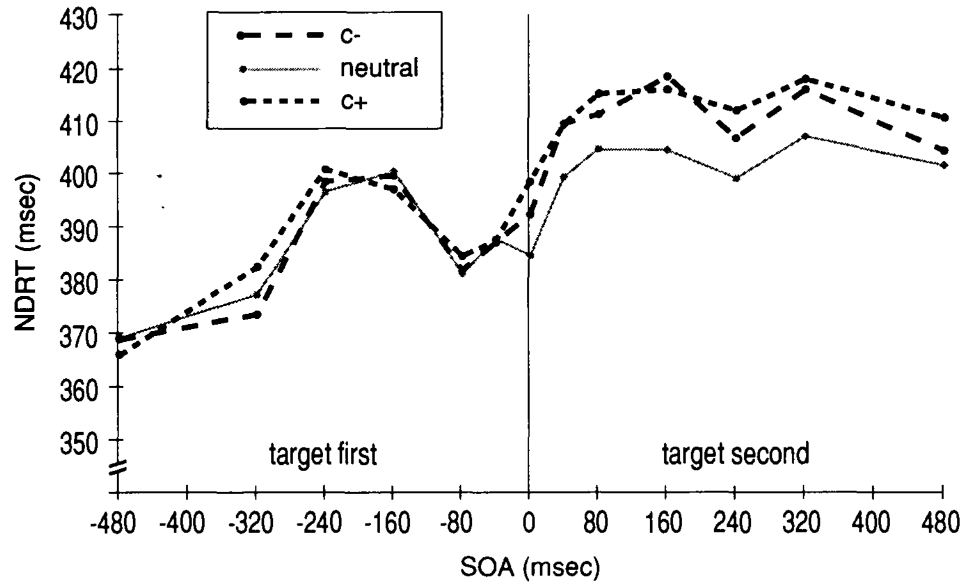


FIGURE 4.35. RESPONSE TIMES: Mean response times for correct name-decisions as a function of case-priming condition and prime-target stimulus onset asynchrony for Experiment 5. Each mean is based on 288 trials for one subject. (Results for ten additional subjects obtained over the SOA-range -160 to +240 msec are shown in Figure A4.35 below.)

29.23, p<.001 while significant effects were not obtained for post-exposed primes (SOA range -480 to -40 msec), F(2,4697) = 0.34, p>.001. Interaction effects between SOA and congruency were neither significant for pre-exposed and simultaneously presented primes, F(12,5449) = 0.52, p>.001, nor for post-exposed primes, F(10,4697) = 0.67, p>.001. The main effect for SOA for both pre- and post-exposed and simultaneously presented primes was significant; F(6,5449) = 20.03, p<.001 and F(5,4697) = 46.90, p<.001 respectively.

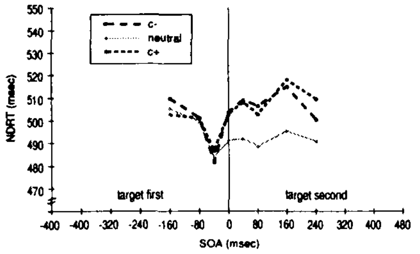


FIGURE A4.35. RESPONSE TIMES: As for Figure 4.35 mean correct name-decision response times for ten additional subjects over the SOA-range -160 to +240 msec. Each mean is based on 288 trials. (See Appendix 3 for further details.)

Mean correct case-decision response times for each SOA-level for each priming condition are represented in Figure 4.35. Difference values, as before, were obtained by subtracting the means for the case-congruent and case-incongruent priming conditions from the means for the neutral

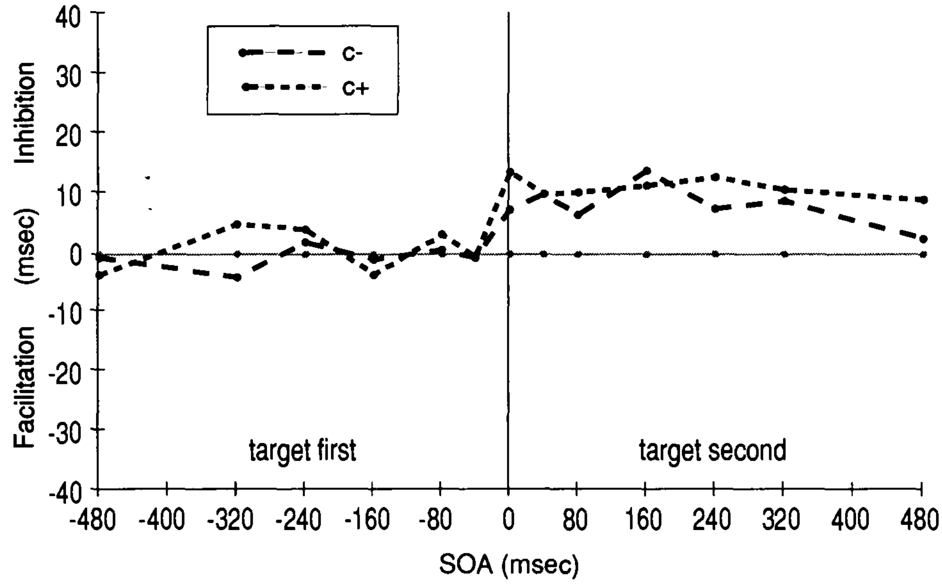


FIGURE 4.36. RESPONSE TIMES: The difference in mean name-decision response times for case-congruent and case-incongruent priming in relation to neutral priming as a function of prime-target stimulus onset asynchrony for Experiment 5. (Results for ten additional subjects obtained over the SOA-range -160 to +240 msec are shown in Figure A4.36 below.)

condition. These differences in response time are shown in Figure 4.36, again with the terms 'inhibition' and 'facilitation' respectively referring to positive and negative differences. The SOA for the prime and target was measured in relation to the onset of the target so that positive SOA values indicate prime pre-exposures while negative SOAs show prime post-exposures.

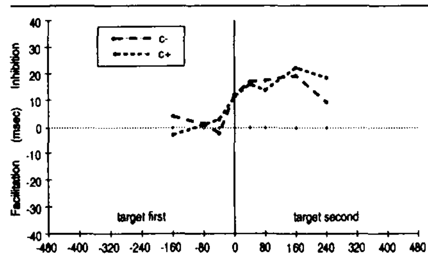


FIGURE A4.36. RESPONSE TIMES: As for Figure 4.36; The difference in mean response times in relation to neutral priming for ten additional subjects over the SOA-range -160 to +240 msec. (See Appendix 3 for further details.)

Inspection of Figures 4.35 and 4.36 suggests that response latencies for case-congruent primes are significantly longer for simultaneously presented and pre-exposed primes. This observation was confirmed by a series of one-way ANOVAs carried out across congruency conditions for each SOA and followed by the use of the Newman-Keuls method when a significant ($p<.05$) congruency-effect was obtained for a given SOA. These tests indicated that case-congruent-priming was established at zero SOA, $Q,754=4.16$, $p<.05$ and remained significant throughout the SOA range up to 480 msec, $Q,786=3.35$ $p<.05$. Although Figure 4.36 suggests a reliable trend for case-incongruent-priming effects it was found that these were non-significant at SOAs of zero, $Q,754=2.31$, $p>.05$, 80 msec, $Q,765=2.41$, $p>.05$ and 480 msec, $Q,786=1.00$, $p>.05$. For the remaining SOAs of 40, 160, 240 and 320 msec case-incongruent-priming effects were significant at the $p<.05$ level; $Q,770=3.94$, $Q,784=4.44$, $Q,794=3.01$, and $Q,796=3.16$ respectively.

For SOAs of zero and above congruent case-decision response times were on average 11.4 msec more than those for the neutral condition. Latencies for incongruent name-primes averaged 8.4 msec more than the neutral condition. Congruent case-priming effects for SOAs of zero and above remained close to the average value of 11.4 msec throughout the SOA range. Although Figure 4.36 suggests that the time-course of incongruent priming relative to the neutral condition is subject to some variation over the positive SOA range it should be noted that this was not detected by the congruency-SOA interaction ANOVA quoted earlier.

The mean name-decision response time across all priming conditions and SOAs was found to be 396.6 msec, SD=47.7. This value closely matched that for Experiment 2 (391.2 msec). The variation of response time with SOA also followed a similar pattern to that of Experiment 2; response latencies increased from 367.6 to 398.2 msec over the SOA range -480 to -240 msec and then decreased to 391.3 msec at zero SOA. This was followed by a sharp increase to 410.1 msec over the next 80 msec SOA before response latencies levelled-out. The minimum disruptive effect on response latency at an SOA of -480 msec apparent from Figure 4.35 is also consistent with the previous experiments. Similarly it was observed that very few primes were visible at this SOA value on account of trial-terminating responses being made before the occurrence of a prime. In the above respects, then, there is a stability across experiments.

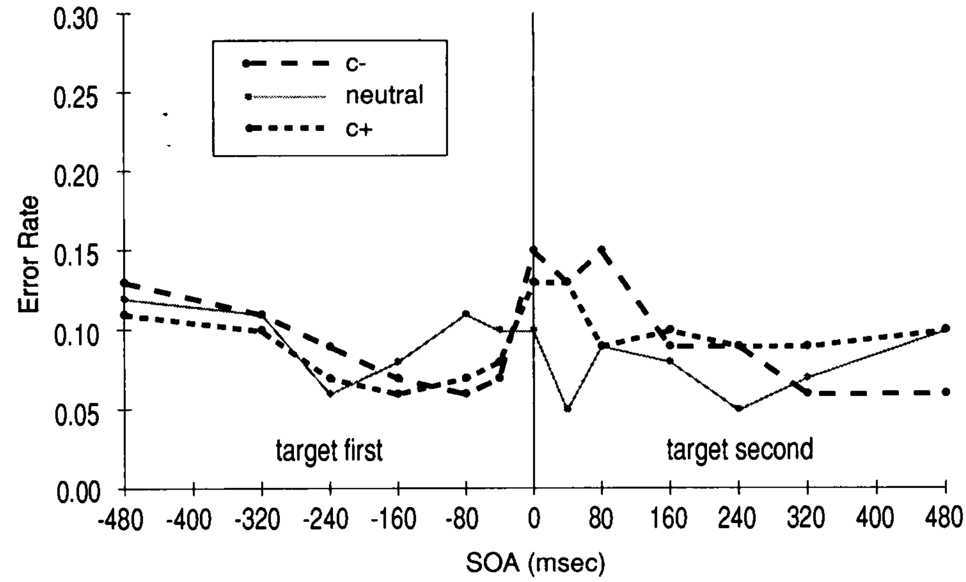


FIGURE 4.37. ERRORS: The variation in error rate for case-primed name-decisions according to priming condition and stimulus onset asynchrony for Experiment 5. Each mean is based on 288 trials for one subject. (Results for ten additional subjects obtained over the SOA-range -160 to +240 msec are shown in Figure A4.37 below.)

Error Rates

Figure 4.37 shows the error rates for the three priming conditions as a proportion of the total responses for each condition at each SOA-level and Figure 4.38 shows the same error rates for the congruent- and incongruent-case-priming conditions in comparison to the neutral condition. From an inspection of the above figures the following trends

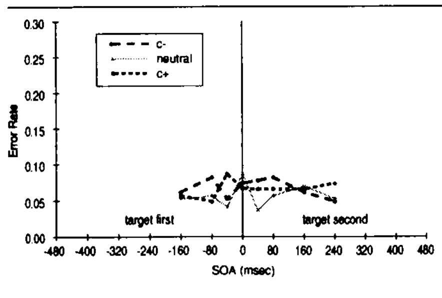


FIGURE A4.37. ERRORS: As for Figure 4.37; the variation of error rate for ten additional subjects obtained over the SOA-range -160 to +240 msec. (See Appendix 3 for further details.)

may be apparent: error rates decrease between from 0.12 at -480 msec SOA to 0.08 at -80 msec SOA before increasing slightly on average and levelling-out at about 0.09 for the remaining SOAs. For pre-exposed primes condition-dependent effects upon error rate occur; this observation being largely corroborated by the results of a series of Chi-squared tests carried out for each SOA. These are now detailed.

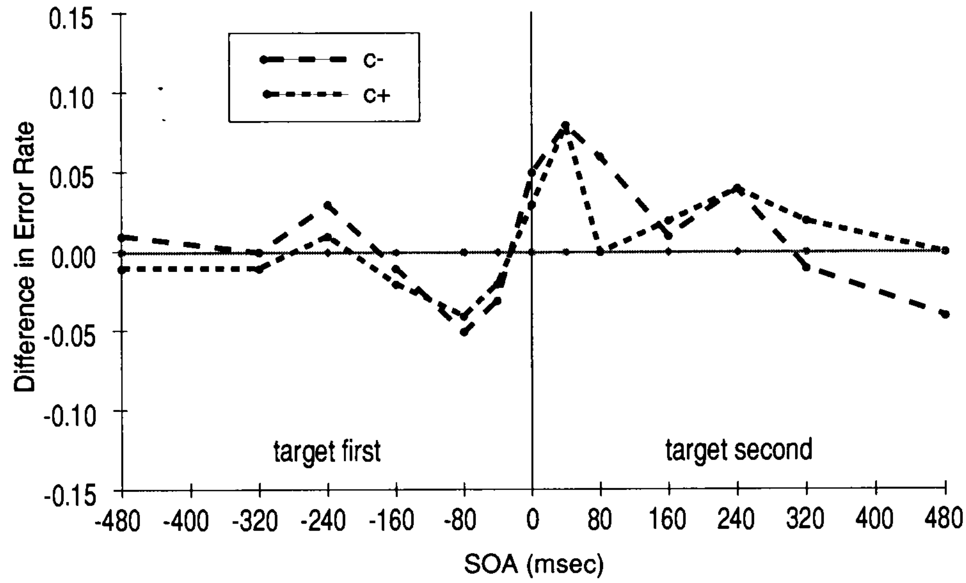


FIGURE 4.38. ERRORS: The difference in error rates for congruent and incongruent priming in relation to neutral priming as a function of prime-target stimulus onset asynchrony for Experiment 5. (Results for ten additional subjects obtained over the SOA-range -160 to +240 msec are shown in Figure A4.38 below.)

The pattern of relative differences in error rates between the priming conditions has similarities to pattern of relative response latencies. An examination of Figure 4.38 suggests that error rates for the congruent and incongruent conditions were generally in excess of those for the neutral condition. However case-priming effects were significant only at 40 and 80 msec SOA, $\chi^2 = 13.0$, $p<.05$, and 7.7, $p<.05$ respectively.

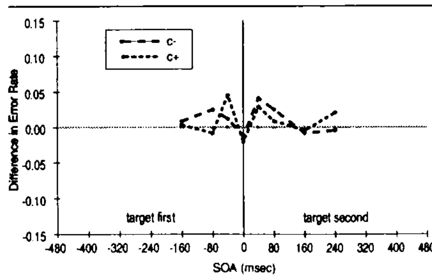


FIGURE A4.38. ERROR RATES: As for Figure 4.38; the difference in error rates in relation to neutral priming for ten additional subjects over the SOA-range -160 to +240 msec. (See Appendix 3 for further details.)

A point of interest with regard to the error rates is that both name-congruent and name-incongruent priming produces a peak in the +40 to +80 msec SOA range. One difference with this peak and those of the earlier experiments is that it is delayed with respect to the onset of response-latency effects. A further difference with the present error findings is that for pre-exposed primes congruent-priming also results in an initial high increase in the occurrence of errors.

Additional-Subject Data

As with the preceding experiments results were obtained for ten additional subjects over the restricted SOA range -160 to 240 msec. Name-decision response latencies averaged 500.3 msec, that is approximately 104 msec longer than for the main subject. This increase in response time was again accompanied by a lower error rate for the additional-subjects in comparison to that for the main subject; an overall error rate of 0.069 compared with a figure of 0.102 for the main subject.

Comparison of the pairs of Figures 4.35 and A4.35 (Page 238) through to Figures 4.38 and A4.38 suggests that relative priming effects obtained with the additional subjects were substantially similar to those obtained for the main subject. The trends apparent from Figure A4.36 (Page 239) were largely supported by Newman-Keuls tests. However it should be noted that incongruent case-priming was not significant at zero SOA ($Q,657=1.85$, $p>.05$) and at 240 msec SOA ($Q,673=2.18$, $p>.05$). Additionally, and unlike the main-subject data where significant case-priming was obtained with congruent primes at zero SOA, the trend apparent in Figure A4.36 was not found to be significant ($Q,657=1.74$, $p>.05$).

The effect of priming on the overall pattern of error data for the additional subjects was less evident than with the main subject. Although Figure A4.38 (Page 242) suggests a similar trend at 40 msec SOA this was not found to be significant ($\chi^2 = 3.82$, $p>.05$).

In response to a leading question regarding which of the two typographic cases the horizontal bars more closely resembled the answer from each of the ten additional subjects was to the effect that it was neither one nor the other. Appendix 3 may be consulted for further details of additional-subject data.

DISCUSSION

A comparison of the overall duration of name-response latencies for the main subject of 396.6 msec in the present experiment and 391.2 msec for Experiment 2 with the case-response latencies of 379.6, 376.6, and 379.8 for Experiments 1, 3 and 4 is consistent with the assumption that the encoding of name-information requires more time than case information. As with the earlier experiments the presence of a prime appears to slow down target responses. Again this is evident from the increase of response latencies for pre-exposed primes in comparison to that for post-exposed primes. In terms of general effects the time-course is similar to those already obtained and thus will not be further discussed.

Case-priming condition-dependent effects appear to have been obtained in spite of the possibility of masking by the target case content. A notable feature, however, which emerges from the results is the relative increase in response latencies of both the congruent and incongruent priming conditions in comparison to the neutral condition for SOAs of zero and above. Rather than the expected facilitation for the congruent condition an inhibitory effect is apparent. This inhibitory effect is also matched by a relative increase in error rates for congruent in comparison to neutral priming. One possible explanation for this is that priming may result from a word-attribute other than typographic case. Since the letter-strings used in the congruent condition differ from the dashes used in the neutral condition in terms of such physical factors as area or brightness then these may have been responsible for any effects. However, if selective priming is derived from the 'general' effects of double stimulation (Taylor, 1977) it is difficult to account for the relative differences in latencies between the congruent and incongruent conditions which appear with SOAs of 240 msec and above. Although these differences are small they appear from inspection of Figure 4.36 (Page 239) to be reliable and, furthermore, they correspond with the trend in relative differences in the error rates for the two conditions as shown in Figure 4.38 (Page 242). In sum, then, it may be argued that the obtained priming effects are linked to information pertaining to typographic case.

The onset of a significant case-congruent priming effect upon name-decision latency at zero SOA for the main subject is consistent with the prediction based on the relative speeds of encoding case- and name-information. It was assumed here that with cross-attribute priming both single- and dual-coding structures would allow the products of case-processing to be communicated to those mechanisms responsible for name-encoding. Although the relative magnitude of the effect for congruent primes does not accord with expectation the time-course is nevertheless consistent with the models so far discussed. The early availability of case information in relation to name information to response mechanisms may similarly accounts for the trend in the inhibitory effect detected at zero SOA for case-incongruent primes.

The inhibitory and disruptive priming effects for congruent case-primes may have occurred for different reasons than those for the inhibitory and disruptive effects for incongruent primes. This may be inferred from the already noted diverging trends in the response latencies at the longer SOAs as well as from the time-course of error rates. In Figure 4.37 (Page 241) the continued decrease in error rate with increasing SOA for incongruent case-priming contrasts with a relatively small change in error rate with SOA for congruent primes.

If the inhibitory effect on name-decision latency with congruent primes is due to their case-content then an explanation for this is not obvious. If an attempt is to be made to account the departure from the predicted effects then a question which initially arises concerns the locus. Two possible loci are, of course, represented by the broad groupings of mechanisms suggested by the distinction that has been made between encoding and responding processes. An encoding account of the inhibitory effect arising from congruent case-primes is difficult to formulate on the basis of existing spreading-activation and PDP models. This difficulty is also retained in view of the results of Experiment 4 which have been taken to suggest that the inhibitory effects that may be allowable within the encoding stage according to some PDP models do not occur.

So far inhibition at the responding stage has been accounted for by a response-competition mechanism where inhibitory effects should only be expected upon the occurrence of covert incongruent responses. If this explanation is to be pursued then a source of codes giving rise to incompatible responses must be determined.

Generation of Incompatible Codes

If incompatible case-codes are generated at the locus of analysis of case information then the relatively large facilitatory effect of case information on a case-decision task obtained in Experiment 1 would be difficult to explain. A more likely locus for the generation of an incompatible code may be that for semantic-encoding. One possibility is that an incompatible semantic representation of a case-code is generated in the way that antonyms are frequently generated as associates to verbal input (e.g., Kucera & Francis, 1967). The difficulty with this explanation, however, is that similar antonymous associates might also be expected with name-priming on case-decision since this may also involve a semantic link. However the inhibitory effects that might have arisen from this were not apparent from the name-priming effects obtained in Experiments 3 and 4. Although it is possible that the generation of antonymous associates within semantic-encoding mechanisms may vary according to whether input is verbal or nonverbal this does raise a more difficult question as to why this may be so. Although a rule may be added to existing models to allow for such an asymmetry it is, perhaps, worthwhile avoiding a post hoc approach and instead more carefully re-examining those structures that already exist.

Another, and perhaps in some ways simpler, explanation arises if the range of possible outputs from the encoding of nonverbal visual information is considered. Although on the presentation of a string of letters the code for a specific typographic case may be activated there remains the possibility that other codes may also be generated. These, for example, may vary from a code signifying the presence of an object, its colours, or, that it consists of a collection of letters. In comparison to these latter attributes the code for a particular typographic case-form such as 'upper' or 'lower' may be more specific and elaborate and demand a relatively extended analysis. In the same way that an encoded typographic case-form may output to a semantic system so also might the other encoded attributes. Furthermore the more general attributes of input such as its presence, or, that it consists of a string of letters may be encoded in less time than the more specific information such as that pertaining to a particular typographic case-form. In this event it is possible that more general letter-string information may be available relatively early to a semantic-encoding system. This more general letter-string information might in turn lead to the activation of more specific concepts related to letters including typographic case. Such a process is represented diagrammatically in Figure 4.39. In this situation any one specific form of typographic case may not be invoked in preference to another. On this basis the early registration of the presence of letters in general may give rise to the activation of the semantic representations of both upper- and lower-case. In this way semantic-codes or their verbal counterparts that are incompatible to a case-prime may be outputted to responding mechanisms. As a result the response to the incompatible code may in turn have to be suppressed. As discussed earlier with both single- and dual-coding models it is also possible that the magnitude of the inhibitory effect arising from response-competition may be greater than any cross-attribute facilitatory effect obtained through encoding. Thus the net effect for both compatible and incompatible case-primes upon name-decision may be inhibitory.

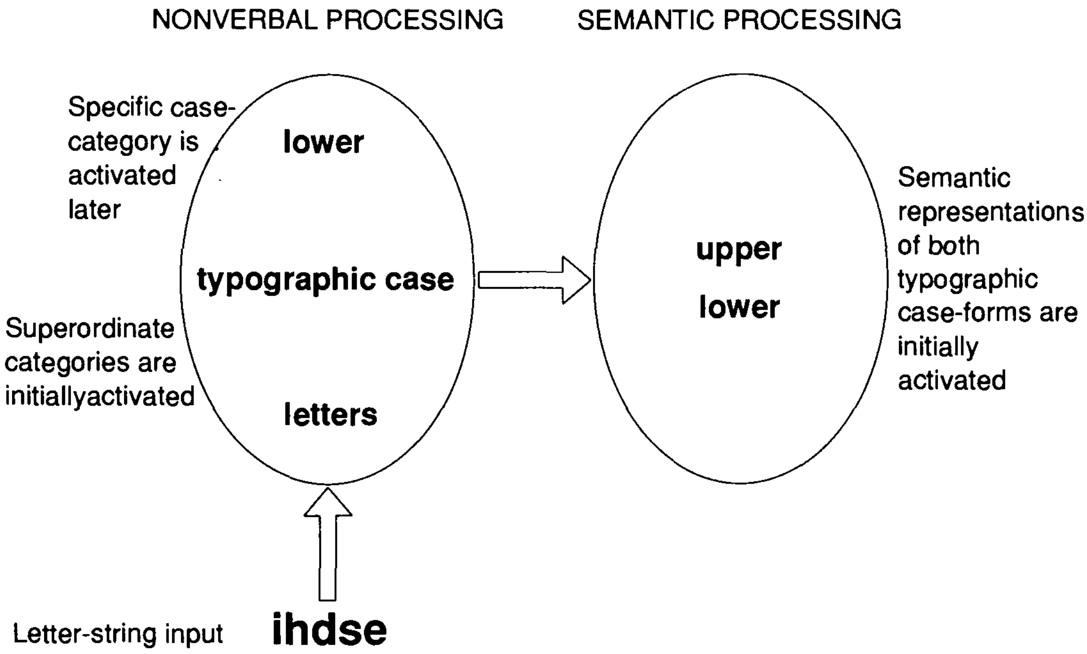


FIGURE 4.39. A diagrammatic representation showing how generalised case-information derived from letter-string input may lead indirectly to the generation of both upper-case and lower-case codes within a semantic system. (See text.)

The consistency of the above account with the cross-attribute effect obtained in Experiments 3 and 4 where congruent name-priming facilitated case-decisions may now need to be explained. Here facilitatory and inhibitory effects were obtained with congruent and incongruent primes respectively. These results may have arisen because the verbal component of a stimulus may not be interpretable in the variety of ways pre-semantically that a nonverbal component may be. In other words there is no analogy between the early encoding of verbal material and the encoding of the nonverbal qualities of a letter string which may range from its colour to its specific case-form. It is reasonable to argue that a word has to be encoded either as a specific verbal entity, or, as a number of specific verbal sub-entities. In this event if, for example, the word 'upper' is to trigger the semantic representation of a specific typographic case then the representation for upper-case is likely to be activated before an associated concept such as lower-case.

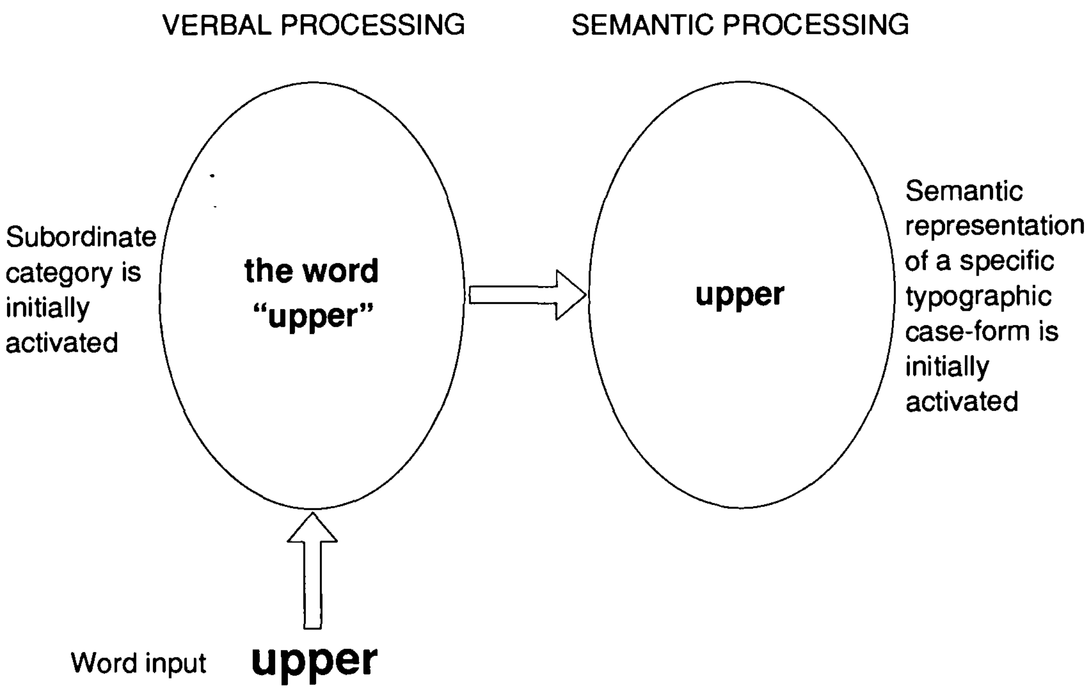


FIGURE 4.40. A diagrammatic representation showing how the input of a case-denoting word-name may result in a congruent case-code being generated before an incongruent case-code. (See text.)

This contrasting process is shown in Figure 4.40. The implication of this for response-competition is that an interfering code derived from the name-input congruent with target case will arrive at the responding stage after the code that is consistent with the target and thus suppressive mechanisms will not take effect.

Although the above explanation of inhibitory effects with congruent case-priming of name-decision may be elaborate the explanation is based upon a reinterpretation of the existing basic mechanisms that have been postulated rather than relying on the introduction of new ones. The explanation, however, may only be regarded as partial in so far that it does not explain the apparent difference in priming effects between congruent and incongruent priming for SOAs of 240 msec and above. From Figures 4.36 and 4.38 (Pages 239 and 242) it appears that this difference is reliable, and, that if incongruent codes are generated in the congruent case-priming condition then their effects are more enduring than those generated from incongruent primes. There appears to be no obvious explanation for this.

CHAPTER 5

GENERAL DISCUSSION

The effects upon performance occurring in some cross-attribute Stroop-like interference studies, and within-attribute priming studies involving letters or words such as those carried out by Posner and Snyder (1975), Neely (1977), and Taylor (1977) were examined in Chapter 3. It was noted that studies involving cross-attribute priming were frequently interpreted in terms of inhibitory effects arising from inconsistent information while within-attribute priming studies were frequently considered in terms of facilitatory effects where prime and target information were consistent. In view of the processing possibilities introduced in Chapter 1 it was suggested that some fundamentally similar mechanisms may be common to both within- and cross-attribute priming. It was argued that such similarities might be evident in the time-course and magnitude of effects obtainable. It was also argued that this was not always apparent from comparisons among existing studies because of the differing forms of stimuli, prime-target onset asynchronies, and task requirements used. Some uniformity in these respects was attempted with the present series of experiments. In this chapter the extent to which the present data suggest that there could be mechanisms in common to within- and cross-attribute priming effects is considered. The main empirical results are firstly summarised along with some initial assumptions and interpretations. The results are then discussed in relation to some possible processing mechanisms that could be involved in the tasks. The assumptions made in interpreting the results in relation to the processing mechanisms are stated within the context of those discussions where they apply. The extent to which the data constrain some of the processing options is considered along with some discussion of further empirical tests relating to the interpretations.

SUMMARY OF THE MAIN RESULTS

General Observations

The results of the series of typographic case experiments described in the previous chapter suggest that the presence of contextual information can affect the performance of speeded categorisation tasks. A prime that was visible before a response to a given target was made resulted in the slowing down of both case- and name-decision responses in comparison to primes which occurred after a response. This 'general effect' occurred regardless of prime-target congruency. Pre-exposed primes had a greater slowing effect than post-exposed primes. However, with all of the experiments, as the prime pre-exposure interval increased there was a slight trend towards shorter response latencies.

Possible explanations for the faster responses with increasing SOA may be made in terms of both the increasing effect of arousal and the decreasing effect of psychological refractivity over the first 500 msec. With arousal, Posner and Boise's (1971) work suggests that the presentation of a prime results in a general lowering of response time with prime pre-exposures up to about half a second (see Appendix 2). If the effects of psychological refractivity are interpreted in terms of, either, recovery from the presentation of an initial stimulus, or, the organization of a response, then shorter response latencies would be expected at longer SOAs. Arousal and psychological refractivity are discussed in more detail in Appendices 1 and 2. The present findings are consistent with those on alertness reported by Posner & Boise (1971), and Drazin's (1961) work on refractivity. Further implications of alertness and refractivity are discussed below in relation to selective priming effects.

Comparison of Case- and Name-Response Latencies

Although the experiments were not designed to allow direct comparison of name- and case-response latencies, overall it was noted that name-decisions for both the main subject and additional subjects were consistently found to take more time than case-decisions; the differences ranging between about 10 and 30 msec.

Selective Effects

Selective priming effects were obtained according to the consistency of prime and target content. In all the experiments the onset of significant selective effects was marked by a relatively sharp transient both in relative response latencies and error rates located at, or shortly after, zero SOA. In comparison to relative response latencies, error rates fell rapidly away with increasing SOA from the sharp peak, or rose from a trough, established at the shorter SOAs. The selective effects are now summarised according to each experiment.

Case Priming of Case-Decision

The time taken to categorise a string of letters in terms of typographic case was affected by prior exposure of a similarly constructed letter string. Case primes consistent with their targets result in speeded responses and were subject to lower error rates in comparison to a prime consisting of a row of dashes. Similarly, case primes inconsistent with post-exposed targets increased response times and produced a higher rate of error in comparison to dashes. Priming effects were not apparent for primes which coincided with or followed their targets.

It is assumed that the selective priming effect is due to the typographic case content of the primes. It has already been argued in Chapter 4 that other factors, such as stimulus area, that might have given rise to condition-dependent effects were either counteractive or minimal.

A further assumption that has been made in interpreting the relative priming effects is that since the dashes comprising the 'neutral' primes were not readily associated with either of the typographic cases by any of the subjects they may be regarded as providing a baseline against which any condition dependent effects can be compared. If this assumption is accepted then, for pre-exposed primes, case consistency results in a relative facilitatory effect and case inconsistency an inhibitory one.

Although the neutral condition has been regarded as a baseline some further initial assumptions have been made when considering the magnitude of facilitation and inhibition in relation to the possible effects of alertness and psychological refractivity. With regard to alertness the greater frequency of presentation of identical stimuli with the neutral condition may result in a habituation effect so that response times could be comparatively long. If this relative effect increases as alertness builds up over the SOA range then facilitation could be overestimated and inhibition underestimated at longer SOAs. To some extent, however, it is also possible that the relatively small area occupied by neutral primes may, in comparison to the other priming conditions, contrast with the targets. This could result in a higher level of general arousal following neutral primes and lead to faster responses and thus an underestimate of facilitation. This may offset the effects of any habituation resulting from the more frequent repetition of neutral primes. With regard to refractivity, the more frequent and less complex dashes comprising the neutral priming condition may result in less initial processing and result in faster responses. If the effects of refractivity are greater at the shorter SOAs then inhibition could be overestimated and facilitation underestimated in this region. The combined effects of alertness and refractivity may be complex when it comes to interpreting the magnitude of facilitation and inhibition. However, the present assumption is that estimations of facilitatory and inhibitory priming are not excessively distorted as a result of any differential effects that might arise from neutral priming. This is in view of the possibility that the effects may to some extent be self-compensating, and, that in the congruent and incongruent priming conditions the salient case-priming attribute is also extensively repeated, even though different letter strings are used.

Name Priming of Name-Decision

A similar pattern of relative priming effects to case priming was obtained when targets were primed and categorised in terms of the case-denoting words ‘upper’ and ‘lower’. That is, name primes consistent with their targets resulted in speeded responses and were subject to a lower error rate in comparison to the prime word ‘ether’. Similarly, in comparison to ‘ether’ pre-exposed name-primes inconsistent with targets resulted in increased response times and a higher rate of error. Priming effects were not apparent for primes which coincided with or followed their targets.

Although the priming conditions and categorisation task have been described in terms of word-name this does not necessarily exclude the possibility that other forms of information relating to a given word, such as semantic information, could be implicated. Since the primes were always in a different typographic case from their corresponding targets it has been assumed that the relative priming effects could be related to name content rather than the repetition of physically identical stimuli. Additionally, the relative priming effects of information derived from other word attributes such as typographic case were assumed to balance out across trials. Again, facilitation and inhibition in relation to a ‘neutral’ condition were assumed on the basis of subjects not associating the word ‘ether’ with any one of the case denoting words. As with case priming any underestimation or overestimation of facilitation or inhibition is assumed to be minimal. This is because, in terms of alertness, although habituation may arise from the neutral condition the congruent and incongruent primes are also extensively repeated and any condition dependent effects are assumed to be small. Unlike the neutral condition in the case priming experiment, the stimuli in all name priming conditions occupied a similar area and it is assumed that any differentiation in levels of general arousal arising from this is unlikely to give rise to significant effects. The complexity of the stimuli in all conditions is also assumed to be similar so that differences in priming effects resulting from refractivity can be regarded as minimal.

Name Priming of Case-Decision

The priming effects obtained with the case-denoting words 'upper' and 'lower' also followed a similar pattern as in the first two experiments. Here case-decision times were shorter for consistent targets and longer for inconsistent targets in comparison to when 'ether' was used as a prime. Error rates were also affected according to prime consistency as before. Facilitation and inhibition were assumed on the basis that subjects were not biased in their association of 'ether' with any one typographic case. The effect of name priming on case-decision has been regarded as an example of cross-attribute priming. The cross-attribute effects differed from the above 'within-attribute' priming effects in that they were subject to a delay; namely facilitatory and inhibitory effects were not obtained unless the prime preceded the target by at least 80 msec. This compares with significant facilitatory and inhibitory effects obtained at 40 msec SOA in the case of within-attribute priming.

Case and Name Priming of Case-Decision

Combined case and name priming of case-decisions also resulted in facilitatory and inhibitory effects when pre-exposed primes were used. When the prime and target cases matched, response times were shorter and error rates lower in comparison to a neutral condition consisting of dashes. Similarly, longer response times and higher rates of error were obtained for those conditions with a case mismatch.

The relative effects of name information combined with case information on case categorisation of a target differed according to case consistency; in particular facilitation increased when there were both case and name consistencies in comparison to case consistency alone whilst inhibition did not increase for case and name inconsistency in comparison to case inconsistency alone. However, in the latter instance a difference in error rates was apparent. In comparison to case consistency alone, the combined effect of case consistent and name inconsistent primes was inhibitory. With incongruent case primes a relative facilitation was found when primes were additionally name consistent, however, net inhibition was obtained in relation to the neutral condition.

Differences in the time-course of case- and name-priming were also apparent from the results with combined case- and name-primes. Consistent with the results of the previous experiments it was found that case-priming effects were obtained earlier than name-priming effects. This pattern was found both with regard to response latencies and error rates.

Case Priming of Name-Decision

A final experiment which sought to examine the effect of case priming on name-decisions produced anomalous results; in comparison to the neutral condition, consisting of a row of dashes, inhibitory effects were obtained with both consistent and inconsistent primes. Here the relative effects on both response latency and error rates were found to be of a similar magnitude. The time-course of effects was marked by the onset of significant case-congruent priming at zero SOA. Although case-incongruent priming was not significant until an SOA of 40 msec SOA was reached, a trend in inhibitory effects was nevertheless apparent at zero SOA.

As with case priming of case-decision, refractivity could have contributed towards an overestimate of inhibition at shorter SOAs while alertness could have had both facilitatory and inhibitory consequences for neutral primes. Again it is assumed that these effects were likely to be marginal, or self-compensating.

PROCESSING MECHANISMS

In this section the case and name priming results are considered in relation to some possible processing mechanisms that might account for performance in the decision tasks. A major assumption here is that task performance can be characterised in terms of processing following a series of stages responsible for encoding input, decision making, selecting and effecting a response. Initially the discussion focuses on the extent to which the obtained data may be consistent with mechanisms relating to these stages when considered independently. Further possible empirical work relevant to some of the interpretations is also outlined. Since performance may be related to more than one mechanism this section leads on to a consideration of how the above mechanisms may, collectively, account for the priming effects. To begin with, then, some possible processing mechanisms are outlined and discussed in relation to the data.

Expectancy

One way in which expectancy may operate in relation to the selective priming effects is for subjects generate a set of expected targets after a prime has been presented (Posner, 1978). Targets which fall within this set are recognised more quickly than those which do not. According to Posner and Snyder (1975b) it may take a relatively long period of time (i.e., a few hundred msec) to generate an expectancy set and so any priming effects obtained as a result of this will be slow acting. The effect is regarded as strategic and processing of expected targets is speeded regardless of their relationship to the prime. Similarly, processing of unexpected targets, again regardless of their relationship to the prime, is slowed. Expectancy, then, could give rise to facilitation and inhibition.

If the present case priming effects are to be interpreted in terms of the strategic nature of expectancy as outlined above then it is necessary to identify possible means whereby target categories might be predicted from priming information. The experiments were designed so that it was not possible to predict the task category on any given trial on account that the probability of occurrence of each category was equal, not predictable from the prime, and the order of presentations randomised and unknown to any subject. However, this alone may not rule out the possibility for strategic effects. For example there could have been an expectancy effect arising from subjects being aware of the existence of congruent priming conditions. If, for example, there should be a tendency for congruent prime-target pairs to attract attention and be remembered then an expected target set could result so that a bias towards faster responses for the congruent conditions could arise. The time scale over which this could occur would depend upon the time required to generate an expectancy set. Some guidance in this respect may be sought from work already introduced in Chapter 3, such as that on letter matching carried out by Posner and Snyder (1975), and in category priming carried out by Neely (1977). From these studies it is assumed that expectancy effects would be unlikely to occur early in the time-course such as at 40, 80, or 160 msec. Relatively few stimulus categories were available in the present case priming experiments, and hence the expectancy set could be a small one. However, Posner and Snyder's (1975) figure of some 300 msec for the onset of strategic effects, for example, may remain a valid guide in that the number of possibilities regarding an expectancy set in their work is assumed not to be dissimilar to those in the present work.

If strategic priming effects did occur then it would be more likely that they would be detectable with increasing SOA. However increases in facilitation and inhibition which might have been indicative of expectancy as described above were not apparent within the longer SOA range covered by the main subject data. Although expectancy effects could remain a possibility the present results do not easily lend themselves to this interpretation.

The role of expectancy could, of course, be further examined with the present case priming experiments if trials were re-run in blocks where the probability of the prime being consistent with the target category was varied. In view of Posner and Snyder's (1975) work it might be anticipated that primes highly predictive of consistent targets could give rise to an increase in facilitation for consistent targets and inhibition for inconsistent targets with increasing SOA, assuming strategic factors are relatively slow acting. Further to this, and to some extent analogous to Neely's (1977) work, the time-course of effects could also be examined when primes were more likely to mismatch targets. With consistent targets, facilitation at shorter SOAs (presently assumed to be non-strategic) would be expected to give way to inhibition at longer SOAs. With inconsistent targets, inhibition at shorter SOAs (again assumed to be non-strategic) could be followed by facilitation at longer SOAs. In addition to a possible transition from facilitation to inhibition, and vice-versa, being attributable to a contrast between automatic and strategic effects the above empirical work may provide more direct support for priming mechanisms identified by Posner and Snyder being applicable to decision tasks of the type used in the present work. It would also be of interest under the new experimental conditions to see if, contrary to Posner and Snyder (1975), and Neely (1977), inhibitory effects which could be attributed to automatic processes continued to be obtainable.

A further test that could be carried out in relation to expectancy as a possible priming mechanism would be to prevent conscious identification of prime information. This might be achieved using the pattern masking techniques outlined in Chapter 2. Apart from this modification the case stimuli used and the task requirements could remain essentially unaltered. If effects were obtained with masked primes then it could be argued that expectancy would be unlikely to be involved. However, there are difficulties in interpretation here since the mechanisms involved in subliminal priming could be different from those involved with supraliminal priming. Moreover, if subliminal priming was not obtained then, on this argument alone, besides expectancy remaining viable, mechanisms other than expectancy dependent upon supraliminal prime information may not become operative. Although reservations have already been expressed regarding the difficulties in establishing criteria for sub-threshold priming and obtaining reliable effects the technique may nevertheless remain useable if finer quantitative measures are not required. Testing for expectancy effects may not be demanding in this respect.

Spreading Activation

A mechanism introduced in Chapter 1 that could account for priming effects during encoding is spreading activation. Unlike expectancy, spreading activation has been characterised as automatic and relatively fast acting (Posner & Snyder, 1975). Activation may spread among a number of interconnected processing units. These units have been referred to as 'nodes'. Each node can represent a concept or an entity of information such as a feature, a letter, or a word. Each node is also capable of assuming a level of activation. Activation may be derived from input to the processing system and spread from one node to another along links or connective pathways. Information from activated nodes is made available for further processing. It has been assumed that a change in the level of activation of nodes requires a finite period of time. On this basis it has also been assumed, for example, that information from nodes may be made available relatively quickly if the nodes are already partly activated. In this way one input may facilitate the processing of another.

Although Posner and Snyder (1975) have argued that spreading activation can facilitate processing, other models based upon this mechanism may also allow for the possibility of inhibitory effects. For example, with Rumelhart and McClelland's (1981) interactive activation model, nodes acquire levels of activation which may vary from a minimum negative value through a resting level to a maximum positive value. Nodes with a positive activation level are deemed active while those with activation at or below zero are considered inactive. A distinction between activity relating to nodes and the nature of connections between nodes was also made; active nodes may have both excitatory and inhibitory effects on other nodes according to the nature of the interconnections while inactive nodes have no effect. The combined effect on an individual node may be excitatory or inhibitory depending upon the relationship between it and the array of nodes or 'neighbours' to which it is directly connected. As a consequence the level of activation may be raised or lowered in accordance with an averaging effect of the connections. On this basis it is possible that priming information consistent with a given stimulus would raise the level of activation while inconsistent information would lower the level. Accordingly congruency-dependent facilitatory and inhibitory effects are possible and, ignoring other mechanisms, the data from the first three experiments could be viewed as generally consistent with this interpretation. Difficulties arise, however, in accounting for the priming effects obtained with the two further experiments; when case information primed name-decisions (Experiment 5), and, when combined case and name information primed case-decisions (Experiment 4).

In the discussion of Experiment 5 it was argued that the inhibition obtained when congruent case information primed name-decisions may have resulted from the early availability of activated nonverbal information that could be associated semantically with an opposite name-response. A possible explanation for this was that in order for a given typographic case form to access a verbal referent it might first access codes representing typographic case in general. From this superordinate category multiple codes may be activated so that the verbal labels pertaining to both case subsets (i.e., 'upper' and 'lower') may be derived. As a result of this a net inhibiton could have arisen from the effects of the inconsistent verbal component. This process was summarised in Figure 4.39 (Page 248).

With the results using combined primes in Experiment 4 it was found that facilitation of case-decisions increased with both case and name consistent information in comparison to case consistency alone. This has already been accounted for by spreading activation on the assumption that with case and name consistency a greater number of nodes related to the target category become activated thereby reducing the time required for recognition. Although an increase in inhibition could similarly be predictable for case and name inconsistency in comparison to case inconsistency alone, this was not found. If it is assumed that spreading activation during encoding is at least partly responsible for priming then the above asymmetry could result from facilitation applying to case and name information and inhibition only to case information. Although this is a logical possibility it is not clear, however, from the encoding mechanisms described why this might occur. A further encoding possibility is that within-attribute effects could occur in the absence of cross-attribute effects but, again, given cross-attribute effects do occur, a question remains concerning the locus of association for representations in different modalities. A possibility which is consistent with spreading activation as characterised by those such as Posner and Snyder (1975) is that within- and cross-attribute facilitation could occur without inhibition. Here there are obvious difficulties with the similar and complementary facilitatory and inhibitory processes that might be predictable from Rumelhart and McClelland's (1981) interactive activation model. Other possibilities remain, of course, in that increased facilitation with combined case and name priming could be due to mechanisms other than spreading activation. These are discussed later.

The rapid onset of priming as indicated by the early sharp transient from nonsignificant to significant relative effects in the time-course for each experiment may be regarded as consistent with Posner and Snyder's (1975) notion of spreading activation being fast acting. The time-course characteristic in all the experiments is of interest by virtue of its marking the onset of priming as well as the occurrence of an abrupt transient in effects. Again, these qualities can be discussed in relation to a model such as the interactive activation model suggested by Rumelhart and McClelland (1981). This model is characterised by the spread of activation between layers of nodes. In relation to models of this type 'bottom-up' processing has been used in reference to the rule that the activation of a 'lower' layer of nodes concerned with earlier analyses of input may only affect the state of activation of a 'higher' level of nodes concerned with later analyses. 'Top-down' processing may be similarly interpreted as activation at a higher-level only affecting a lower-level. An interactive model by definition is one characterised by both top-down and bottom-up processing (Rumelhart, Hinton & McClelland, 1986). The relevance of interactivity to the time-course of the present results is now considered.

If encoding is interactive then a build-up of activity may be imagined where, as a result of input, some lower-level nodes reach a firing threshold relatively quickly and begin to activate higher-level nodes. These higher-level nodes may in turn activate or reactivate lower-level nodes. This process may continue so that the concurrent build-up in activation at different levels occurs over a period of time. In Rumelhart and McClelland's (1981) interactive activation model the speed at which this build-up occurs depends essentially upon the time it takes individual nodes to reach a firing threshold. Within such a framework it is assumed that recipient nodes will reach a firing threshold earlier if they are already partly activated. This state may arise through the prior presentation of compatible contextual information. This mechanism is consistent with the finding that within-attribute facilitatory encoding effects were obtained with pre-exposed congruent priming information. This is also in line with Taylor's (1977) notion of a secondary specific effect where the processing of one stimulus is influenced by the completed (or, at least, partly completed) processing of another stimulus.

The above notion of interactivity also raises the possibility that the effects of pre-exposed primes could also have resulted from a top-down activating component. In this case early priming information encoded at a higher level could reactivate lower-level nodes so that they fire earlier with the subsequent presentation of compatible input. This process can also be extended to priming with simultaneously or post-exposed contextual information. A parallel may also be drawn between this and a form of 'backward priming' that has been postulated by Koriat (1981). Here the suggestion was that information activated as a result of prior target input could reactivate input resulting from a subsequently presented prime. As a result of this both target and priming information may be processed together. It can be argued that this type of mechanism may accord with Taylor's (1977) notion of a primary specific effect where the processing of one input is influenced by the concurrent processing of another. In the present work, however, no within- or cross-attribute facilitation was obtained with simultaneous or post-exposed primes. The same can be said for inhibitory effects if the relative speed of processing of case and name input (discussed below) is allowed for when case information primed name-decisions (Experiment 5). This is also of interest in relation to another related feature which typifies interactive nodal models; the speed with which a given node may reach a threshold for firing depends upon the number of activated nodes to which it has excitatory connections. With this in mind it may be argued that the effect of simultaneously presenting compatible context and target information may also be to increase the number of activatory interconnections for a given set of nodes so that speeded encoding would be expected. On this basis it would again be expected that the facilitatory priming effects exhibited at positive SOAs in the experiments carried out would also be obtainable at zero SOA and, perhaps, at shorter negative SOAs. The data were not consistent with this however.

If it is assumed that spreading activation acts as a priming mechanism then one explanation for the lack of primary specific effects might be that the presentation of either priming information alone or target information alone was sufficient to produce a saturation. That is, for example, information carried by the target would be sufficient to activate all nodes relevant to a given input category to some point above the firing threshold so that no speeding of target-encoding would result on availability of simultaneously presented compatible contextual information. Such an explanation may, however, be questioned if it is assumed that the increase in facilitation with consistent case and name primes in comparison to case consistency alone (Experiment 4) is attributable to encoding activation. This would suggest that saturation did not result from either case or name priming information alone.

Another, and perhaps more direct, explanation for the lack of a primary specific effect is that encoding can proceed successfully on a bottom-up basis with minimal interactivity. Here the method relating to the priming experiments may be relevant. Firstly, target encoding at all levels could proceed successfully on the basis of minimal information because of the high familiarity due to the large number of experimental repetitions. Secondly, input was presented clearly (i.e., it was not visually degraded) so that processing gains from access to simultaneously available or post-exposed contextual information would not be great. If the above account is tenable it suggests that while interactivity among nodal levels may occur, especially with unfamiliar input, encoding is nevertheless possible with minimal or even zero interactivity.

The apparent lack of a primary specific effect stands in contrast to Glaser and Düngelhoff's (1984) work with cross-modality priming of picture naming and word categorisation. Here the existence of priming effects with simultaneously presented or post-exposed stimuli was taken to support a temporal proximity rather than a temporal precedence argument. In view of the above rationale it is possible that the effects obtained with simultaneous or post-exposed primes by Glaser and Düngelhoff could have occurred because subjects were relatively unfamiliar with the stimulus items used. Their findings are further discussed in relation to the present data in the next section.

If it is assumed that with increased encoding interactivity, selective priming effects build up over a measurably longer period of time then two possible experimental manipulations may provide further tests of the above interpretations. Firstly, familiarity with the targets could be reduced by increasing the number of different items falling within a given task category. This might result in a less abrupt transient with effects extending into the simultaneous or post-exposed priming region. Secondly, visual degradation of target stimuli could increase the time over which stimulus features become integrated. Here though, the form of stimulus degradation may be important. While pattern masking introduces spurious features which could weaken bottom-up input and so enhance contextual effects, the same may not hold with contrast reduction, or a light flash mask (Humphreys & Bruce, 1989). If either, or both of the above manipulations results in increased interactivity occurring over a relatively long period of time then it is possible that priming effects might be obtained from simultaneously presented, or, even post-exposed contextual information. It may be noted that possible variation of the effects of stimulus degradation according to context also has implications regarding the locus of facilitatory and inhibitory effects; this is further discussed below.

Decision Making

In relation to the tasks in the present experiments decision making can refer to a number of functions; for example, one job of a decision mechanism might be to decide upon the task-related category to which encoded target information belongs (e.g., 'upper case'), while another job might involve selecting and releasing an appropriate response programme (e.g., 'right-hand keypress').

With regard to deciding upon the category of input in relation to an experimental task one possibility is that some form of comparison may occur with a given encoded target attribute against a stored set of representations (e.g., Seymour, 1979). In the present experiments one question which arises concerns whether such a 'task set' might only contain information identical with the task-related attribute of a stimulus, or, whether other attributes could be represented or available. For example, if decisions were based upon the task attribute alone then within- rather than cross-attribute effects would be expected to occur at this stage. The further possibility remains, of course, that both case and name information could affect a comparison process so that cross-attribute effects could be accountable in this way. This point is further discussed below where the data are considered in relation to other possible priming mechanisms.

A decision making process such as the above may be subject to facilitatory effects if items within a task set were activated in accordance with priming information. Although inhibition may arise from inconsistent primes, as with encoding, it is difficult to account for the finding with combined primes in Experiment 4 that increased facilitatory effects were obtained from case and name consistencies while increased inhibitory effects from case and name inconsistencies were not. Again, as with encoding, this difficulty in accounting for the data might be resolvable if the above decision process was subject to facilitation alone. If inhibition did occur, however, it is also possible that the lack of increase in inhibitory effects could have resulted from decisions being based upon case information alone. If this was so, other mechanisms would be responsible for the increase in facilitation with case and name congruent primes.

As a result of an initial decision process a response consistent with a prime could be pre-programmed and the threshold for effecting it lowered so that the occurrence of consistent oncoming target information could result in the earlier release of the program. This could lead to both within- and cross-attribute facilitation according to whether decisions were made on the basis of case or name information. However a response pre-programmed as a result of priming information could also be a source of inhibition. This possibility is discussed in the next section.

The onset of the transient obtained in the time-course of the priming effects can also be considered in relation to decision-making processes. In the same way that encoding thresholds may be raised or lowered from pre-exposed stimuli so also might the threshold of activation of the elements of a memory set involved in comparison. Similar threshold effects linked with the release of a response program might also be applicable. If it is assumed that priming results from prior activation of an item in a memory set, or responses consistent with the prime being pre-programmed then it would be expected that pre- rather than simultaneously or post-exposed primes would give rise to effects. This, again is consistent with the within-attribute data and, assuming case-encoding requires less time than name-encoding, with the cross-attribute data.

Relative Speed of Processing and Response Competition

In Chapter 3 relative speed of processing and response competition were introduced as one possible account for the Stroop effect. With this interpretation it is assumed that different stimulus attributes are encoded in parallel at different speeds up to a point where responses are generated. It is further assumed that there is a limited-capacity response channel, or buffer, to which the first available response is admitted (e.g., Morton, 1969; Treisman, 1969; and Neumann, 1980); a competition for final output. If stimulus attributes convey information leading to incompatible responses then a response to one attribute may be delayed if time is required to suppress a prior potential response to another attribute. If response compatible information is conveyed by different stimulus attributes then one possibility is that the same response programme could be activated. On this basis output based upon a target attribute may continue unimpeded. However, there are a number of other possibilities concerning sequences of compatible and incompatible responses. These are now considered in relation to the present results. Although the term response competition has been used in relation to interference or inhibition arising from incompatible responses to different stimulus attributes, it should be noted that the use of the term in the present discussion is taken to include responses to the same or different attributes in a sequence of stimuli. Furthermore, the possibility of facilitatory effects is also considered.

Although not a response competition effect as such, it is possible that an apparent facilitatory effect could arise with a target response if output proceeds on the basis of a consistent response which becomes available first. This might be regarded as a simple 'headstart' effect. With the present within-attribute experiments, for example, the error peak at very short pre-exposures of inconsistent primes, and matched to some extent by a trough for consistent primes (e.g., Figures 4.9 and 4.13, Pages 154 and 173), could suggest that output proceeds on the basis of prime information alone. However the possibility that a simple headstart effect might account for the data throughout the positive SOA range is considered unlikely. This is because, with consistent prime-target pairs, it would be expected that the magnitude of facilitation would be of a similar order to the prime-target onset asynchrony, and, increasing prime pre-exposures would result in similar increases in the magnitude of facilitation; this clearly was not the case. The error peak could have occurred as a result of problems of distinguishing the prime from the target in terms of case relevant information; this might have led to the generation of inappropriate responses. Alternatively, if responses were generated according to prime and target identity then response suppression could have been disrupted. If the latter explanation holds then, in the same way that response suppression may be liable to disruption at an early stage in time, it is also possible that once established it gains a 'momentum' which is difficult to reverse. This suggestion may be drawn from the observation for the main subject data at longer SOAs where the error rates for incongruent priming drop dramatically, and on some occasions (Experiments 1, 4, and 5) appear to fall below those for the neutral condition. In other words the act of suppressing a given (erroneous) response could make it more difficult to re-initiate the same response. There may be parallels between this process and the psychological refractory effect.

If it is assumed that presentation of both prime and target stimuli results in the generation of potential responses which can interfere then the present data can be interpreted in terms of response competition. In the case of within-attribute priming, for example, a conflict would be expected with the pre-exposure of a prime inconsistent with a target and the time-courses of within-attribute inhibitory effects obtained in Experiments 1, 2, and 4 are consistent with this. If an incongruent prime and target were presented simultaneously then there might also be a chance that a response consistent with prime information may gain initial control of the output channel and have to be suppressed with a resulting inhibitory effect. However, apart from a slight but non-significant trend with the main subject data from Experiment 1, inhibitory within-attribute effects were not obtained with incongruent conditions at zero SOA. One possibility, of course, is that competing responses were not produced; a distinction between prime and target information derived from the relative spatial arrangement of the stimuli within the visual field might have been instrumental here. However, if responses were generated to primes as well as targets then, again, a further mechanism would be necessary so that responses to targets rather than primes were outputted. If response suppression is to be initiated, prime information would have to be distinguished from target information. In addition to information from the spatial arrangement of the stimuli, other than for simultaneously presented primes and targets, temporal information could have been utilised since the trials were blocked in terms of onset asynchrony. The role of temporal information could be further investigated through mixing pre- and post-exposed primes within block of trials. The extent to which temporal information might be utilised in distinguishing prime from target information might be reflected in the error rates for choice decisions.

With response competition considered in relation to cross-attribute priming the relative speed of processing of the different stimulus attributes has also to be taken into account. With the present experiments it is assumed that case categorisation responses are generated in less time than those for name categorisation. This assumption is consistent with the shorter case-decision latencies obtained in comparison to those for name-decision across experiments. Further to this, the relative speed of processing account is consistent with relative delays in the onset of within- and cross-attribute effects. For example, while significant inhibitory (and facilitatory) effects were obtained at 40 msec SOA when case information primed case-decisions (Experiment 1), similar effects were not obtained until at least 80 msec SOA with name-priming of case-decisions (Experiment 3). This relative delay in the name-priming effect in comparison to case-priming was also apparent from the results obtained with the combined case- and name-primes used in the case-congruent condition in Experiment 4. These latter combined priming results are, however, more complex and will be further discussed below. A similar interpretation may also be applied to the reliable trend in case-priming on name-decision which was established from zero SOA (Experiment 5) in comparison to name-priming of name-decision which did not take effect until an SOA of 40 msec was reached (Experiment 2).

The interference that may result from a sequence of responses has been considered in relation to the combined priming effects in the discussion of Experiment 4. In order to interpret the findings it was assumed that both primes and targets generate potential responses which are subject to interference. With combined primes there were further possibilities. Firstly, responses could have been generated for the task-relevant stimulus attributes only (i.e., case information with Experiment 4). In this case competition, or mutual facilitation, of responses in relation to an output buffer would not be expected with cross-attribute information. While this could account for the lack of relative inhibition with target-incongruent case and name information combined, the same does not hold for the converse relative facilitation with combined target-congruent information. In this latter respect, however, other mechanisms such as those for encoding could have been responsible. Secondly, the possibility that responses could be generated for name as well as case information can also be considered. If a response to case information was produced in less time than that for name information then, given a sufficient pre-exposure interval, a sequence consisting of a response to case information followed by a response to name information would be available before that generated in accordance with the target's case. That target-inconsistent responses from the case and name content of a prime were treated as a singular response to be suppressed was considered possible in view that inhibition from combined case and name incongruent primes was similar in magnitude to that for incongruent case primes. Here the assumption was that more time would be required to suppress two responses if they were treated separately. The absence of a relatively greater combined inhibitory effect in response latency may be contrasted with the error results for the same priming conditions where a trend in relative effects was apparent. Here the probability of suppression of responses to priming information being disrupted could depend upon the number of potential responses resulting from information consistent with each priming attribute. Again, this may be distinct from the time costs involved should response suppression be successful. It has already been noted that combined congruent case and name information resulted in a relative increase in facilitation. Apart from other mechanisms, a possible account for this is that mutual priming between consecutive responses could have occurred, either on entry to or within a response buffer, or, with the subsequent execution of responses. However, in the absence of other sources of facilitation, a mutual priming account would not be consistent with the net facilitation from combined case-congruent and name-incongruent primes in view of the intervening inconsistent response from the name component. Although facilitation could be a response effect, other sources of facilitation are also likely.

If consecutive potential responses resulting from a prime differ with one, therefore, being inconsistent with the target then response suppression could occur. This could account for the relative inhibition obtained with incongruent name information combined with case-congruent primes. Although a potential response to the congruent case component of the prime would be the first to be generated and control output this would also be followed by a potential incongruent response arising from the name component which might have to be suppressed before a response to the target could be outputted. With case-incongruent and name-congruent information combined, inhibition could arise from the suppression of the initial inconsistent case response. It might be noted here that in the absence of inhibition from other sources, it would be difficult to account for the overall inhibition obtained with case incongruent combined with name congruent primes in comparison to the neutral condition if only those responses immediately prior to the target were suppressed.

Relative speed of processing and response-competition can also be further considered in relation to the relative magnitude of case priming effects. In Chapter 4 it was argued that with a serial response buffer the degree of inhibition resulting from the suppression of an unwanted motor program may be the same regardless of its source. Here inhibition was seen to depend upon the nature of the unwanted motor program rather than how it was invoked. On this basis it would be expected that the degree of inhibition would be the same regardless of whether priming was within- or cross-attribute. If response suppression was solely responsible for inhibition then this expectation would be consistent with the general uniformity of the magnitude of the inhibitory effects obtained across the different experiments. However, here it should be noted that for the main-subject data in Experiment 2, where incongruent name information was used to prime name-decisions, inhibitory effects were found to be greater. It is possible that this latter departure from prediction may have arisen in view of the difficulties of cross-experimental comparisons of the magnitude of condition-dependent changes in response latency. The similarities otherwise obtained with the corresponding additional subject data may, to some extent, bear this out. These possibilities, however, are not discussed in detail since such comparisons of priming effects across experiments are made with caution and could be misleading.

In sum, relative speed of processing and response competition could account for the inhibitory effects obtained. An apparent facilitation could arise from a headstart effect, however, it has been argued from the present data that this might only occur at very short SOAs. Although an encoding account for facilitation has been suggested the possibility remains that facilitation could also result from response processes. Empirical tests which might further locate sources of facilitation and inhibition are discussed in the next section.

Processing Mechanisms: A Collective Summary

On considering the above mechanisms a number of accounts for the priming effects obtained remain possible. However, it has been argued that some mechanisms more easily accommodate the present data than others. There were difficulties with expectation as an account for priming at the relatively short prime-target onset asynchronies used. Similarly, there were problems in accounting for facilitation across the SOA range in terms of a simple headstart effect where output might have been produced on the basis of prime information when followed by a consistent target. From the mechanisms that have been considered, some appear more viable than others when considered independently in relation to the data. These mechanisms, however, have also to be considered in terms of their mutual compatibility with the results. This is now attempted in the form of an overall summary. Through this summary a view is suggested of processing as relevant to the experimental tasks used.

From the series of processing stages posited earlier, input is assumed to be initially subject to encoding. Here automatic spreading activation could account for facilitatory effects obtained according to the consistency of priming information with the target. Assuming interconnections exist between case and name representations it is possible that an increase in the level of activation of a given representation in one modality could result in an increase in activation for consistent information in another modality. On this basis not only are cross-attribute effects possible but they could also be subject to relative increases according to the overall consistency of information within and across priming attributes. This has been argued to account for stronger facilitatory effects with combined case and name congruent information on case-decisions compared with case congruent information alone. There is a possibility that inhibitory effects could occur with spreading activation. However, if the view is taken that these could be similar and complementary to facilitatory effects (Rumelhart & McClelland, 1981) then there are difficulties in accounting for no relative increase in inhibitory effects being obtained when inconsistent case and name information primed case-decisions. The possibility of only facilitation occurring during encoding is in keeping with accounts such as that by Posner and Snyder (1975).

It has been assumed that the results of encoding are available to mechanisms where a decision concerning the category of information in relation to the task is made so that an appropriate response can be generated. With regard to the mechanisms considered, the possibility that decisions relate only to the task-relevant attribute of a prime (e.g., case information for a case-decision task) raises some difficulties. With a case-decision task, for example, if decisions and responses were based upon case information alone then name priming effects should be located prior to the decision stage. In terms of the mechanisms considered it would follow that facilitatory and inhibitory name priming would be attributable to spreading activation during encoding. However, inhibitory name priming would also imply a capacity for inhibitory case priming during encoding; the difficulties with this have already been noted. In view of this, decisions could be influenced by non-task- as well as task-relevant attributes of a prime (e.g., case and name information for a case-decision task). If decision making involves activation of representations, such as in a comparison process, then, as with encoding, difficulties occur when attempting to account for the asymmetry regarding the increase in facilitation and inhibition with combined congruent and combined incongruent primes respectively on case-decisions. Given this latter problem, sources of inhibition (and facilitation) beyond the encoding and decision stages may be considered.

If potential responses are generated in accordance with both a prime's case and name content then these may be subject to interference. One possibility is that responses may compete for entry to a limited capacity output buffer. On this basis inhibition could arise from early arriving target-inconsistent responses having to be suppressed. It has been argued that the degree of inhibition resulting from suppression of an inconsistent response could be the same, regardless of how the response was invoked. In this respect possible similarities in magnitude of within- and cross-attribute inhibition were noted. The problem of accounting for combined case- and name-incongruent priming effects upon case-decision not being stronger than those for incongruent case priming alone, however, remains. One possible explanation in terms of response competition is that a rapid sequence of response programs generated for case and name information could be treated collectively as a single program. Again, the argument would be that once a response program has been generated the degree of inhibition involved in its suppression could be the same as that for programs from other sources. Although it is possible that a sequence of identical responses consistent with the target could be treated collectively with no relative increase in facilitation, mutual priming remains a possibility. That facilitation could solely arise from mutual priming of consistent responses, however, is considered unlikely in view of the net facilitation with congruent case combined with incongruent name information.

The present results are consistent with facilitation and inhibition resulting from the prior availability of priming information, and, that responses to case information are generated in less time than those for name information. Further issues regarding the temporal relationship between prime and target information are discussed in the next section.

Although it has been argued that some processing mechanisms can account for the present results, difficulties arise concerning the occurrence of inhibition with case priming of name decision regardless of congruency. This is returned to in the next section. Additionally, some alternatives remain concerning the loci of facilitatory and inhibitory effects. Possible further work in this respect is now briefly considered.

One way of investigating whether inhibition could occur in the process of encoding is to examine the effects of stimulus degradation on performance. In particular, it can be argued that early stages of visual processing are slowed if the level of illumination is low, or the contrast reduced (e.g., Wilson & Anstis, 1969). Additionally, Meyer et al. (1975) have found that the difference between lexical decision response times for targets primed by associated and unassociated words varied according to whether they were intact or degraded; responses for associated words were slowed less than those for unassociated words. This interaction was taken to suggest that semantic association and stimulus quality affect a common processing stage, the assumption being that processing is carried out through a series of independent stages (Sternberg, 1969). Meyer et al. (1975) also argued from their further data involving phonemic transformations that the effects of visual degradation (and, hence, semantic association) were likely to influence encoding, with stimulus quality not substantially affecting further processing.

If an analogous approach to the above association effects with word stimuli is applied to the current case priming experiments then it may be possible to obtain data which may further constrain the location of facilitatory and inhibitory effects. Here, for example, the slowing of responses resulting from stimulus degradation should be lessened with congruent priming in comparison to that for a neutral condition on the assumption that facilitation occurs at the encoding stage. If inhibition also occurs during encoding then an interaction effect might also be obtainable with incongruent primes. With spreading activation as a mechanism, for example, information from degraded target features might take relatively longer to activate an appropriate representation if its threshold had been raised as a result of prior inconsistent information. Conversely, the absence of an interaction effect with incongruent primes would be consistent with inhibition not occurring during encoding. Here the validity of results, of course, would depend upon providing neutral priming. Although some difficulties in this latter respect have already been expressed it might nevertheless be fruitful to pursue this line of enquiry in future work. Again, interpretation of such results would assume a sequence of processes to which Sternberg's (1969) additive factor method is applicable. An absence of interaction with inhibitory priming would be informative to the extent that it could, by default, support the argument that decision or responding processes could account for inhibitory priming. In view of the possibility that facilitation may result from the spread of activation during encoding, it would be expected that an interaction effect with stimulus degradation would be obtained with facilitatory priming. However, the possibility that facilitation could also be a decision or response effect would still remain.

One way that response facilitation might be distinguished from encoding facilitation would be to compare the effects of priming using conditions which are response compatible but encoding incompatible. This, for example, could be arranged by using pairs of word and picture stimuli. To illustrate this, the word 'tree' and a picture denoting a tree, and the word 'boat' and a picture of a boat could be used either as primes or as targets. In order to allow the above priming possibilities the occurrence of 'tree' (word) or 'boat' (picture) could be registered by a right-hand keypress and 'boat' (word) and 'tree' (picture) by the left-hand. Encoding incompatibility and response compatibility (e-, r+) would be obtained if, for example, 'tree' (word) was used to prime 'boat' (picture). Similarly, an example of encoding compatibility and response incompatibility (e+, r-) would be when 'boat' (word) was used to prime 'boat' (picture). If facilitation occurs during response processing then this could be detectable through the (e-, r+) condition. If inhibition due to encoding was weak or did not occur, this possibility having been considered above, then detection of response facilitation would depend upon comparison against a neutral baseline. Here, again, the assumption would be that neutral priming could be obtainable, given the reservations already discussed. In the event of inhibitory effects occurring during encoding these might similarly be detectable if (e-, r+) latencies were compared with those for neutral primes. Again, and subject to the same assumptions regarding neutral primes, a net inhibitory effect could be attributable to encoding. The above method could, of course, present difficulties regarding task demands. However, it may be noted that useable data have been acquired by those such as Neely (1977) and Seymour (1977) where the demands resulting from some of the experimental manipulations used may be regarded as not altogether dissimilar.

WITHIN- AND CROSS-ATTRIBUTE PRIMING SIMILARITIES: THE PRESENT RESULTS AND OTHER WORK

Some questions which lay behind the present series of experiments concerned the extent to which the effects of within- and cross-attribute priming could be similar and the extent to which the same processing mechanisms might be involved. It was argued that some similarities between within and cross attribute priming effects that might have been drawn from the results of other experimental work could be obscured by differences in the stimuli and procedures used. As already noted, the present work has sought to compare within- and cross-attribute priming effects where experimental differences have been minimised. Although the viability of some mechanisms which may underlie within- and cross-attribute priming has been argued, further discussion is merited concerning the extent to which within- and cross-attribute priming could be similar, and, how the present results relate to other work; in particular the priming and interference studies introduced in Chapter 3.

The present within-attribute priming results can provide a reference against which other priming results can be compared. Here both facilitation and inhibition were quickly established for pre-exposed primes. With regard to facilitation and inhibition a comparison can be made between these results and those for letter matching reported by Posner and Snyder (1975). While it has been argued that automatic inhibition as well as facilitation was obtained in the case priming experiments, automatic inhibition was not detected by Posner and Snyder. It was argued in Chapter 3 that this might have arisen in view of the difficulties regarding a neutral prime with the letter matching task used, and, that letter matching might have been confounded with prime-target matching. In view of the present results a further observation on Posner and Snyder's work can be made. Namely, assuming response competition could account for inhibition, it can be argued that for Posner and Snyder to have obtained automatic inhibition response competition might also have to be applicable to their results. However, while in the present experiments information carried by an incongruent prime was in itself linked to a response with a particular hand, in Posner and Snyder's letter matching task priming information alone would not have implied a particular handed response. In view of this responses to primes might not have been generated in the way that they could have been with the present case-decisions. In this respect inhibition arising from response competition would not apply.

Response competition, however, could apply to Taylor's (1977) results with letter decisions. From the description of this work in Chapter 3 it is apparent that prime as well as target information corresponded to a given handed response. With regard to inhibition and facilitation, then, the within-attribute findings are consistent with Taylor's (1977) in that relative response latencies were obtained. However, an important difference in relation to the present results is that Taylor (1977, Experiment 1) obtained effects with simultaneous primes and targets. Although neither a case nor name-decision task, Taylor's use of keypress responses according to particular letter identities has similarities with the present work. Also, as with the present experiments, the stimuli were highly familiar to the subjects. This latter point, as argued earlier, could suggest that a strong primary specific effect resulting from an interaction between bottom-up and top-down processing would not be likely. On this basis it is difficult to explain the disparity in the onset of effects. However, one difference which could have been crucial concerns the spatial arrangement of the stimuli. A feature of Taylor's experiment was the use of an asterisk which was not only presented immediately prior to the target but was also in the same spatial position (see Figure 3.4, Page 91). Here it is possible that masking could have arisen, resulting in a short term disruption, so that initial processing of the target was delayed in relation to the priming letters (which were not spatially coincident with the asterisk). An obvious test of this interpretation would be to re-run Taylor's experiment either with the asterisk spatially offset, or, removed altogether. Further to this, it may be noted that significant priming effects were not obtained with letter matching at the shortest SOA of 10 msec in the time-course results reported by Posner and Snyder (1975).

Although similarities in facilitation and inhibition have been noted between within-attribute case and name priming, a difference remains in that more time was required for name responses. If it is assumed that the typographic case-attribute of a word can be treated as a non-verbal, or pictorial, attribute as distinct from its name, or verbal, attribute then one way of accounting for the difference in latencies is in terms of modality specific recognition systems. The single- and dual-coding models introduced in Chapter 1 are illustrative of this. With single-encoding it is held that both verbal and nonverbal information can be represented in a common semantic system; one example of this being the sensory-semantic model of picture and word encoding (Nelson et al., 1977). Alternatively, dual-coding models assume that qualitatively different semantic representations exist for verbal and nonverbal input. An example of this second type of model that was referred to is Paivio and Begg's (1981) dual-coding model of meaning. With either model more time could be required to activate name codes than case codes.

While an encoding account of the difference in case- and name-decision latencies is plausible there is also a possibility that task-related decisions could be modality dependent in this respect. If decisions were based upon semantic representations of input then, with dual-coding, output from each system could be treated differentially. Although this may not arise with single-encoding there is also the possibility that decisions could be based upon output directly from any featural systems involved. This possibility is further discussed below.

Although encoding may initially be modality specific, the mechanisms underlying within- and cross-attribute priming can nevertheless be regarded as similar insofar that representations exist which can become activated, and this in turn has consequences for performance. With either single- or dual-coding, activation of representations in one modality could result in activation of related representations in another modality. With single-encoding, processing converges on a common semantic stage while dual-coding allows links to be made between representations pertaining to each modality. While name priming of case-decision appears consistent with the above within-attribute results in that both facilitation and inhibition occurred, there was a notable departure from this pattern when, regardless of congruency, case information had an inhibitory effect upon name-decisions. That the inhibitory effects might not have resulted from case content is difficult to account for. The possibility that responses in the neutral condition could have been speeded as a result of the reduced complexity or reduced area of the dashes used in comparison to the other stimuli would not be consistent with the results obtained when dashes were used as a baseline in case priming of case-decision. Although the inhibitory effects might be accountable in terms of modified processing mechanisms, or, processing mechanisms other than those already introduced, none were found to be readily applicable. Earlier, this apparently anomalous finding was explained in terms of already introduced mechanisms whereby the presence of priming letters in general might result in the activation of a superordinate semantic code which in turn could activate word names relating to both case forms. From this, it was argued, a net inhibitory effect from response suppression could have arisen. This result nevertheless remains problematic and it is not clear how it can be accounted for in terms of established models. If the inhibitory effects relative to neutral priming are not valid then it could follow that case primes do not differentially affect name-decisions. This could arise if cross-attribute effects did not occur during encoding, or, name-decisions were based on name information only. The possibility that the phenomenon is peculiar to typographic case could be further tested with analogous experiments using other forms of stimuli. However, an analogy might also be drawn with Glaser and Düngelhoff's (1984) investigation of the effects of pictures on word categorization. This is discussed below.

Although facilitation and inhibition were obtained with both within-attribute priming and cross-attribute name priming of case-decision there are possible differences in the strength of within- and cross-attribute effects. Initial inspection of Figure 4.27 (Page 215) may suggest that case effects on case-decision were stronger than name effects. Here, though, it should be noted that Experiment 4 did not allow the effect of the name priming component on case-decision to be directly isolated from the case component. Any facilitation or inhibition due to name information could have been larger than that suggested by the relative increase in effects of case and name information in comparison to case information alone. Indicative of a stronger case effect is the finding that combined congruent case and incongruent name information resulted in a net facilitation. While this observation alone could be accounted for merely by facilitatory effects being stronger than inhibitory effects the same reasoning would also suggest that the congruent name effect could dominate when combined with an incongruent case effect. This was not found; net inhibition was apparent. Although there could be complexities resulting from interaction of case and name effects during encoding it has also been argued that inhibition could have resulted from a separate mechanism such as response competition. In this case the above differences in facilitation and inhibition could be indicative of the magnitude of the name effect. On this basis, then again, it is possible that within-attribute effects on case-decisions could be stronger than cross-attribute effects. If the latter is assumed, then this is also consistent with the earlier single- and dual-coding structures. The means by which cross-attribute priming could occur have already been noted with regard to these models. With single-encoding, for example, if it is assumed that verbal and nonverbal featural systems exist which can both support priming then within-attribute effects would be expected to be stronger than cross-attribute effects on account of prime and target compatibility within each system. Priming, however, could also result from the semantic representation of name or case input being accessed. In this latter situation those such as Carr et al. (1982) and Snodgrass (1984) have noted the possibility of an extreme interpretation where priming effects could be equivalent regardless of input modality. If differences in the strength of priming effects are attributable to encoding then this latter position does not appear to be consistent with the present results. A dual-coding structure could similarly account for the differences insofar that verbal and nonverbal input are encoded in separate systems; within-modality information having a greater influence than information from another modality. The dominance of a case effect can be accounted for in terms of single-encoding if it is assumed that encoding can be selectively directed so that particular stimulus attributes are activated with consequent effects upon performance. This possibility is central to Nelson's (1979) notion of a 'focal code'. Here it is held that encoding can be directed according to the type of task. That the name component should nevertheless have an effect is allowable in view of specific encoding operations having a degree of independence (Nelson, 1979).

The means by which encoding can be selectively directed in Nelson's sensory-semantic model, however, have not been made explicit. With featural systems where activation spreads automatically it is not clear how task-selectivity could operate. However, the effects obtained could occur if direct access of information from the featural systems to decision and response mechanisms is allowed. For example, with reference to the sensory semantic model, Bajo (1988) has suggested that naming a word may not require semantic access. Here the possibility is that a response could be based directly upon the output of the phonemic featural system (see Figure 1.5, Page 51). If output directly from a phonemic featural system is possible then this principle may be extended to provide a model where decisions could be based directly upon the output of the verbal and nonverbal visual featural systems. Comment relevant to this possibility is found in Nelson et al.'s (1977) discussion concerning the significance of the sensory semantic model in relation to memory. For example, it is stated that encoding 'cannot be accurately characterized as consisting of a series of immutable and automatic activations that are specifically and only directed to some pinnacle of semantic-encoding' (Page 494). In the sensory semantic model the codes existing within the visual featural systems are elaborated and effective as 'mnemonics'. For example the recognition of pictures may largely depend upon the nature of their visual rather than their semantic codes. In view of this one possible inference is that a response to a given object (or an attribute such as typographic case used in the present experiments) could involve direct access to the output of a pictorial visual feature system rather than necessarily being entirely semantically mediated. In this sense decision mechanisms could also be implicated in any differences in the strength of case and name effects. The extent to which semantic information might be involved could also be relevant to the Stroop asymmetry typically found between the effects of colours on reading and words on colour naming. Here the two tasks are, in a sense, entirely different. With reading, or word naming, a direct link between grapheme to phoneme conversion could exist and provide little opportunity for irrelevant colour information to have an effect. With colour naming, semantic mediation is necessitated before phonemic information is accessed. This order of operations is explicit in Nelson et al.'s (1977) sensory semantic model (Figure 1.5, Page 51).

Similarities in within- and cross-attribute effects may be apparent from the time-course of effects; a striking feature in the present results being the sharp transient marking the onset of selective priming. Allowing for possible differences in the time required for accessing case and name codes, the results suggest that priming is determined by the order of processing of prime and target information. Although this could be consistent with the encoding, decision and responding mechanisms as described, further consideration of this is warranted in view of the discussion of Glaser and Düngelhoff's (1984) work in Chapter 3. Here a strong form of relative speed hypothesis predicted that the temporal relationship between target and distractor information is both necessary and sufficient for interference effects, while with a weak form of the hypothesis the temporal relationship was only regarded as necessary. From their results with picture and word interference experiments Glaser and Düngelhoff (1984) rejected the strongest form of the hypothesis while retaining the weak form only insofar that temporal contiguity of target and distractor is required if any interference is to occur. This conclusion was consistent with mechanisms which predicted backward priming effects. For example the semantic encoding explanation of Stroop interference (Seymour, 1974, 1977) was cited; this was interpreted in terms of the accumulation of competing internal evidence for target and distracting contextual information which is independent of temporal precedence. However, in Chapter 3, Glaser and Düngelhoff's (1984) conclusion that interference was a function of encoding rather than responding mechanisms was challenged on the grounds that in their experiments, in particular where words were used to distract picture categorization, the range of prime pre-exposures was insufficient to obtain effects with the tasks that they used.

If it is assumed that typographic case can be regarded as a nonverbal, or pictorial, attribute then, in one way, name priming of case-decision can be regarded as analogous to Glaser and Düngelhoff's (1984) word priming of picture categorization. On this assumption the present finding that name information primed case-decisions supports the argument that Glaser and Düngelhoff might have obtained greater increases in word priming of picture categorization with longer prime pre-exposures. If Glaser and Düngelhoff's picture priming of word categorization is also regarded as analogous to case priming of name-decision then two aspects of these results may be noted. Firstly, both sets of results may be accountable in terms of a relative speed of processing argument. That

Glaser and Düngelhoff's (1984, Experiment 2) picture priming effects on word categorization began at the shorter prime post-exposures and extended throughout the pre-exposure range can be seen as having a similarity with the onset of case priming of name-decision at zero SOA. In the present work, though, the variation in the onset of effects according to relative speeds is smaller and more sharply delineated than the corresponding effects of pictures on word categorization. In addition to the wider variety of stimuli used by Glaser and Düngelhoff a possible factor here is that categorization was registered by a vocal response rather than a keypress. That these variants could account for latter quantitative differences in results could, of course, be followed up empirically, either by using keypress responses to picture categories, or, vocal responses to case-decisions. The second aspect of the results concerns the magnitude of facilitation and inhibition. With case priming of name-decision it was notable that inhibition was obtained regardless of congruency. Glaser and Düngelhoff obtained a strong inhibitory effect with incongruent picture primes on word categorization. However, facilitatory effects were obtained with congruent pictures, albeit weak. The earlier account for inhibitory case priming effects on name-decision in terms of a letter string leading to activation of a superordinate category representing typographic case in general could also apply to Glaser and Düngelhoff's findings. That a more general, or superordinate category could be activated for pictures might account for the facilitation obtained by Glaser and Düngelhoff since, rather than using a keypress to indicate specific items, the task was to name a category. Although the latter effects are difficult to explain an important point which nevertheless emerges from comparisons of the present data and those of Glaser and Düngelhoff is that a relative speed of processing and response competition account of verbal to nonverbal, and nonverbal to verbal interference effects could remain viable. This interpretation may be contrasted with Glaser and Düngelhoff's (1984) conclusion in favour of a functional internal processing asymmetry underlying reading and picture categorization, and, picture naming and word categorization.

Some Concluding Remarks

There are potentially many different mechanisms which can account for facilitatory and inhibitory effects obtained in even a small subset of primed choice reaction time tasks. Additionally, more than one mechanism may contribute to any one pattern of effects and complexities arise from many possible competing accounts. One theme in this work has been to examine the extent to which some established mechanisms could account for contextual effects concerning information in verbal and nonverbal form. This account differs from others in that it has been argued that the same mechanisms could remain viable in accounting for priming within and across stimulus modalities. This may apply to the effect of verbal information on decisions regarding nonverbal items as well as nonverbal information affecting decisions concerning verbal information. However, it should be noted that, apart from their possible existence, the applicability of mechanisms may vary according to task requirements and other features of experimental design. There is a sense in which the account is parsimonious in that some existing mechanisms have been reinterpreted to accommodate both previous and present data. However the present results also throw up instances which do not sit easily within existing models; that consistent contextual information can lead to an inhibitory effect on performance is a case in point. Similarly, while the asymmetry between effects resulting from combined congruent and incongruent primes may on the one hand constrain some processing possibilities on the other hand it also leads to further questions concerning the details of underlying mechanisms. In this way these findings could be relevant to how existing models might be developed, or, novel explanations sought.

APPENDIX 1

THE PSYCHOLOGICAL REFRACTORY EFFECT

Experiments investigating the response of single nerve cells to successive stimuli indicate that a cell takes time to recover after 'firing'. This interval of time, typically in the order of 0.5 msec (e.g., Telford, 1931; Craik, 1948), is known as the 'refractory period'. The term 'psychological refractory period' is used in reference to the delay, typically up to 50 msec, that has been found in analogous psychological experiments when subjects respond to the second in a sequence of two successive stimuli (e.g., Drazin, 1961). Although the similarity of the terms suggests analogous underlying processes it is dangerous to make such a comparison. For example the longer interval found in the psychological experiments may be accounted for by the organization of a response to a particular stimulus rather than merely by recovery. Since the examination of responses to successive discrete stimuli is an integral part of many priming studies it is important to consider the nature of any likely 'refractory' effects when interpreting the results.

Many simple reaction studies (e.g., Klemmer, 1956; Drazin, 1961; Bevan et al., 1965) have shown that if a warning signal is given before a target signal then the reaction time to the target varies with onset asynchrony of the two signals in fashion similar to that shown in Figure A1.1. Reaction time approaches a minimum with SOAs of about 1000 msec and may increase as they become longer. If different SOA values are used in random order the results form a similar pattern except that overall the reaction times are longer. Furthermore it has also been well established (e.g., Davis, 1957; Creamer, 1963) that the RT to the second signal varies in a similar manner if a response is required to the warning signal (the first stimulus) in addition to the target (the second stimulus). A

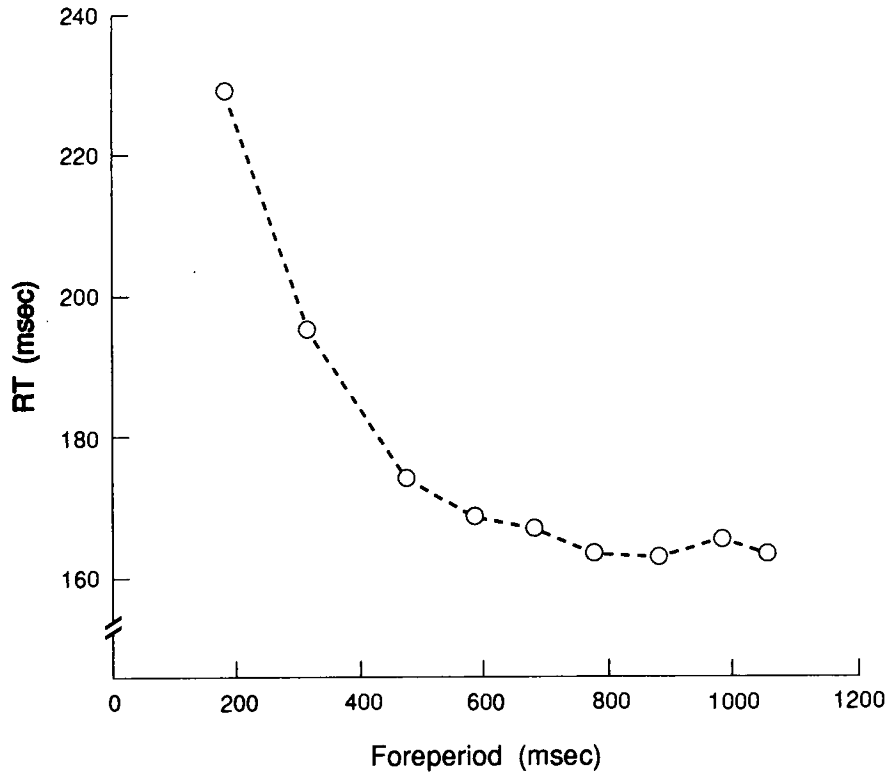


FIGURE A1.1 Variation of reaction time to a target stimulus as a function of onset asynchrony or 'foreperiod' between warning signal and target. (From Drazin,1961.)

feature, then, which is common to the results of the above studies is the lengthening of target RT with shorter SOAs. Another feature of the refractory effect is that it that it persists after extensive practice (Hick, 1948; Davis, 1956; Slater-Hammel, 1958; Gottsdanker & Stelmach, 1971).

One particularly dominant account for the 'refractory' delay was put forward by Craik (1948) and is known as the 'single channel hypothesis'. The idea is that somewhere in the processing sequence there is a time-lag caused by the "building up of some single 'computing' process which then discharges down the motor nerves, ...new sensory impulses entering the brain while this central computing process was going on would either disturb it or be hindered from disturbing it by some 'switching' system." (Craik, 1948, p. 147). Another explanation of the cause of refractory effects may be drawn from Keele's (1973) idea of limited space in information processing capacity. In this context the word 'attention' has been used to describe the total processing capacity available; while some activities require almost total 'attention' and interfere with other activities there is also the situation, particularly with skilled performance, where attention may be divided with minimal interference.

Although the notions of limited space and the single channel hypothesis suggest general principles that may be applicable to refractory phenomena there is, of course, no specific mention of exactly where such 'limited space' or a 'single channel' may be located. If it is assumed that an overall performance involves a number of broad components such as peripheral sensory or motor mechanisms, the identification or categorization of input, then the decisions relating to a plan of action and a repertoire of motor commands which have to be organised appropriately for muscle control (see for example Marteniuk, 1976) so that the carrying out of an action by means of the respective effector mechanisms is allowed. With this context in mind some of the main observations and experimental findings will be outlined.

Where 'limited space' is concerned Keele (1973) argues that information in memory pertaining to familiar situations and appropriate responses may be obtained with very little demand on processing capacity and it is what follows this information retrieval process that demands attention. In other words it is in such things as the initiation and control of movement that refractory effects may occur rather than in a decision mechanism as such. Thus in a situation, such as a reaction time experiment which is highly practised, where the identification of input and selection of a suitable plan of action are assumed to occupy a minimal amount of time, performance should still be limited by the initiation of movement. This was supported by the observation that, even with practice, a psychological refractory period remained (Keele, 1973). However a concern with this explanation rests with the effect of practice upon the processing capacity required for initiation and control of motor movement. It is perhaps also worth noting Keele's points concerning novel situations and responses: the limitation of processing space and also of information processing time in principle applies to all information processes and in an unfamiliar situation verbal labelling of events and selection or construction of suitable responses require relatively large amounts of time and processing capacity. With Keele's model, however, this does not explain the persistence of a refractory effect in experimental situations where a response is required only for the second of two successive stimuli rather than to both.

Davis (1956, 1957, 1959) and Creamer (1963) have found that delays in response to the second of two stimuli still occur even if the first stimulus is presented in a different sensory modality from the second and also if responses are made with opposite hands. These findings may be taken to suggest that the locus of the delay lies within the more extremely peripheral sensory and motor mechanisms. Although responding with opposite hands may invoke separate motor mechanisms of a more peripheral nature this does not necessarily mean totally independent peripheral processes are being deployed; very similar types of motor instructions common to both hands (which may be regarded as relatively peripheral) may be involved and interfere with each other. This has been illustrated by McLeod's (1978) experiment where two letters were presented briefly in succession, with an onset asynchrony of one second, and the subject's task was to press one key if the letters were the same and another key (using a different finger of the same hand) if they were different. This task was probed; an auditory tone to which subjects had to respond was presented at varying points within each trial. One group of subjects responded to the tone (which sounded like 'bip') by saying 'bip' while another group responded by pressing a key with the opposite hand to the one used for indicating letter similarity. In all cases subjects responded as quickly and as accurately as possible. If a probe was presented at or just before the occurrence of the second letter then letter matching responses took longer while a probe presented at other points in a trial had no significant effect. If responding with opposite hands to different tasks is believed to involve separate peripheral mechanisms then one is justified in concluding (as was done at the time) that central processes are responsible for refractory effects. Importantly however, McLeod found that auditory responses to the probe were not significantly affected by a probe's temporal position within a trial. This suggests that more than one categorisation and decision regarding action can take place at one time centrally because when response systems are separated no refractory effects are obtained.

If the results of the above studies are taken together then a possible locus which remains for the refractory effect lies within the organization of some of the motor commands required for certain actions; in particular those that may be common within response modalities such as the limbs. The mechanisms responsible for these functions may be thought of as acting as an interface between any decision mechanisms that may exist and muscle action at the extremities. The requirements of the motor co-ordination necessary in the pursuit of many everyday activities involving the arms and legs suggests closely associated mechanisms in certain areas. The findings from studies concerned with simultaneous actions such as those by Gunkel (1962), and Schmidt, Zelaznik, Hawkins, Frank, and Quinn (1979) are also consistent with this view.

APPENDIX 2

ALERTNESS EFFECTS

The terms 'alertness' or 'arousal' have been used in reference to an overall level of activation in the central nervous system; the level of activation having consequences for the readiness with which stimuli may be processed. Apart from the more dramatic contrasts between such states as sleep and wakefulness two categories of alertness are identifiable; 'tonic' and 'phasic'. Tonic alertness refers to variations in alertness that are detectable over relatively long periods of time such as several hours or a day, or, even in terms of a lifetime. The effects of this have been demonstrated by a number of experiments which show marked changes over the course of a day in performance on such tasks as speeded letter cancelling to the number of digits that can be accurately memorised (Blake, 1971). By way of contrast phasic changes occur over very short intervals of time such as a few hundred msec. Such changes may be controlled voluntarily and may, for example, result from the occurrence of a warning stimulus within an experimental trial. Since the timing of the onset and cessation of experimental stimuli may determine changes in phasic alertness which affect performance the nature of the condition is examined in more detail.

Phasic Alertness

The presentation of a cueing stimulus typically alerts an organism so that subsequent stimuli may be processed more rapidly. Such an 'orienting response' has been investigated by studying the electrical responses of the brain with the aid of an electroencephalograph. Generally electrical responses are detectable from about 10 msec after the onset of a stimulus and last for about half a second (see, for example, Hassett, 1978). A more detailed examination of such 'evoked potentials' which have been averaged over a number of repeated presentations reveals some distinct components; an early component occurs on all occasions and is even detectable during sleep while later components depend on more voluntary attentional processes. A later component that is of particular relevance to reaction time studies is a gradual increase in negative potential, termed the 'contingent negative variation' (CNV). This is obtained in response to a stimulus (to which no response is required) which is used to prepare a subject for the arrival of a second stimulus (when a response is required). Such a CNV may be obtained 200 msec after the onset of a warning stimulus and reach a maximum at about 500 msec, after which it may gradually diminish over a further period of some 500 msec (Posner, 1975). The onset and magnitude of the CNV depends on the SOA between the alerting and imperative stimuli.

There is an established relationship between CNV and alertness in a variety of experiments where one stimulus is used to signal the arrival of a second imperative stimulus and this is further mirrored in time-course changes in reaction time (Posner, 1978). For example with a letter matching task reaction times may fall from very short SOAs by about 50 msec to reach a minimum at SOAs of about 500 msec and then increase slowly with further increases of SOA (e.g., Posner & Boies, 1971). This U-shaped relationship between response time and SOA indicates that alertness builds-up over about half a second and is maintained only for a relatively short time.

Of particular importance to the interpretation of results from some reaction time experiments is whether phasic alerting is general or selective in relation to input content. Posner (1978) cites evidence from letter-matching experiments by Posner and Boies (1971) that suggest phasic alerting results in a general improvement in reaction time rather that having an effect on 'automatic pathways' responsible for encoding more specific information carried by a stimulus. The occurrence of automatic effects was indicated by the increase in relative facilitation in responses in same-letter matches in comparison to different-letter matches that was obtained when the second of each letter-pair (to which a response was required) followed the first with increasing intervals of time from 0 to 500 msec. In addition to the relative effect there was an improvement in reaction time for both matching and mismatching

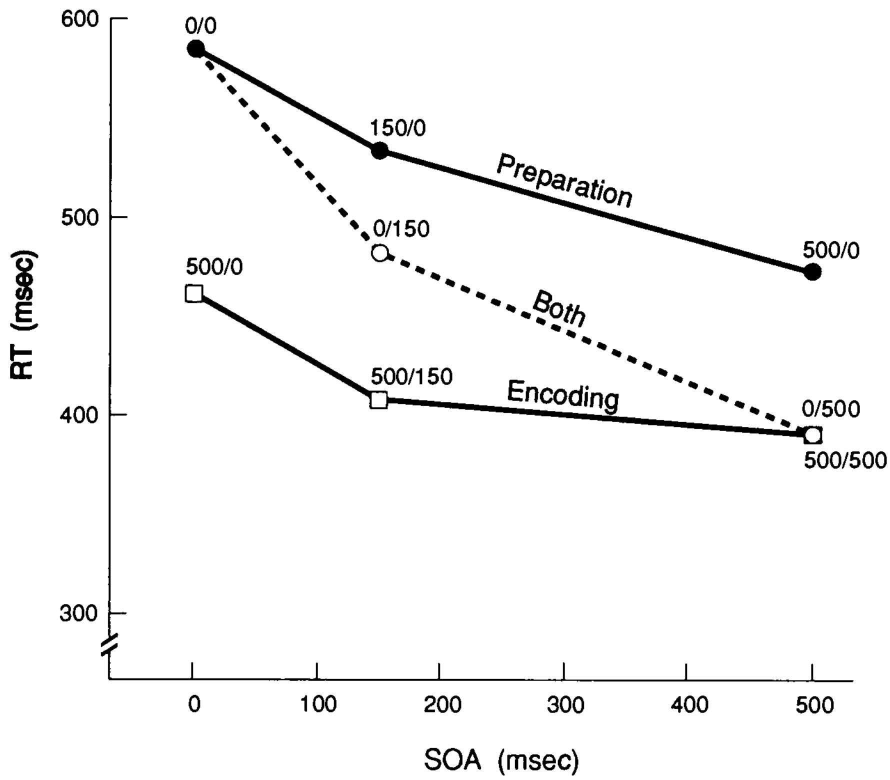


FIGURE A2.1 Response times for a physical letter match task as a function of the warning signal onset asynchrony (represented for each point by the number preceding the oblique) and letter-pair onset asynchrony (numbers following the obliques). (Adapted from Posner and Boies, 1971.)

conditions due to the alerting effects arising from the first letter of each pair also acting as a warning signal. The distinction between the activation and alerting effects was deduced from further experiments where a warning signal other than one of the letter pairs was used. In this case it was found that when the letters comprising each pair were presented simultaneously then response times fell with increase of interval following the warning signal in the manner indicated by the 'preparation' curve in figure A2.1. In a further 'encoding' condition

Posner and Boies also found that if one of the letters of a pair was presented 500 msec after a warning signal, and that this letter was then followed by the second letter to which a matching response was required then, over a range of time separations from 0 to 500 msec between the two letters, response times were some 100 msec less than the preparation condition. This is also shown in Figure A2.1. In this condition it was also found that the warning signal had an equal effect on response times to matching and mismatching conditions. The point 500/0 in the preparation condition is equivalent to the 500/0 point in the encoding condition when there is zero time separation between the letters, this equivalence is reflected in the response times obtained and also indicates that the warning signal used in the encoding condition has an alerting effect. The continuing relatively low response times obtained for the 500/150 and 500/500 points in the encoding condition may be accounted for by the additional effects of pathway activation. A further condition where the first of each letter pair acted both as a warning signal and as a selective cue indicated that activating and alerting effects working together produce a lowering in response time equal to the sum of the two effects separately produced. The results for this 'both' condition are again shown in Figure A2.1. This work suggests that alerting and activation effects are independent; a warning signal thus may not affect encoding processes but instead have consequences regarding the response to the results of input processes. Posner and Boies (1971) also obtained similar results for the nominal matching of letters.

APPENDIX 3

ADDITIONAL-SUBJECT DATA

EXPERIMENT 1: Case-Priming of Case-Decision

Subjects: Three undergraduates and seven postgraduates served as unpaid volunteers.

Total number of responses: 5760
Number of responses falling below 200 msec limit: 9
Number of responses falling above 1000 msec limit: 8
Number of errors: 390

<u>For SOA range -160 to +240 msec</u>:
Main effect for SOA: $F(7,5329)=5.05$, $p<.001$
Congruency effect: $F(2,5329)=12.60$, $p<.001$
SOA/Congruency Interaction: $F(14,5329)=1.63$, $p>.001$

<u>For SOA range -160 to -40 msec (post-exposed primes)</u>:
Main effect for SOA: $F(2,1988)=1.47$, $p>.001$
Congruency effect: $F(2,1988)=0.14$, $p>.001$
SOA/Congruency Interaction: $F(4,1988)=0.16$, $p>.001$

<u>For SOA range +40 to +240 msec (pre-exposed primes)</u>:
Main effect for SOA: $F(3,2672)=1.15$, $p>.001$
Congruency effect: $F(2,2672)=24.88$, $p<.001$
SOA/Congruency Interaction: $F(6,2672)=0.34$, $p>.001$

<u>Congruency effects for individual SOAs</u> (*p<.05):

		Q(c+/N)	Q(c-/N)	Q(c+/c-)	χ^2(errors)
-160	F(2,668)=0.08				1.94
-80	F(2,659)=0.33				1.05
-40	F(2,661)=0.06				5.73
0	F(2,669)=0.15				0.73
+40	F(2,665)=3.52*	2.17	1.56	3.73*	4.02
+80	F(2,664)=9.88*	3.67*	2.59	6.27*	16.92*
+160	F(2,673)=4.78*	1.93	2.45	4.38*	0.92
+240	F(2,670)=8.08*	3.56*	2.06	5.63*	0.37

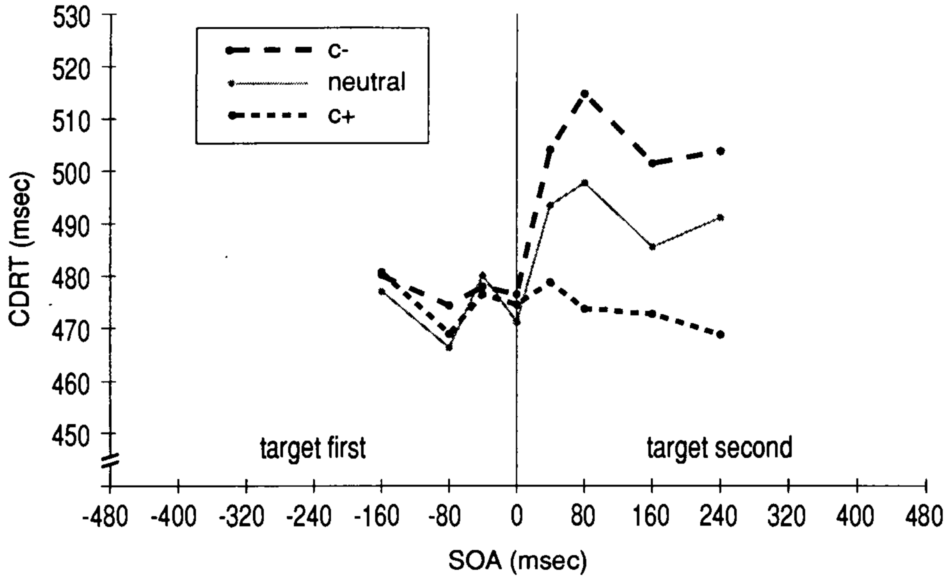


FIGURE A4.7. RESPONSE TIMES (Experiment 1): Mean correct case-decision response times for ten additional subjects over the SOA-range -160 to +240 msec. Each mean is based on 288 trials.

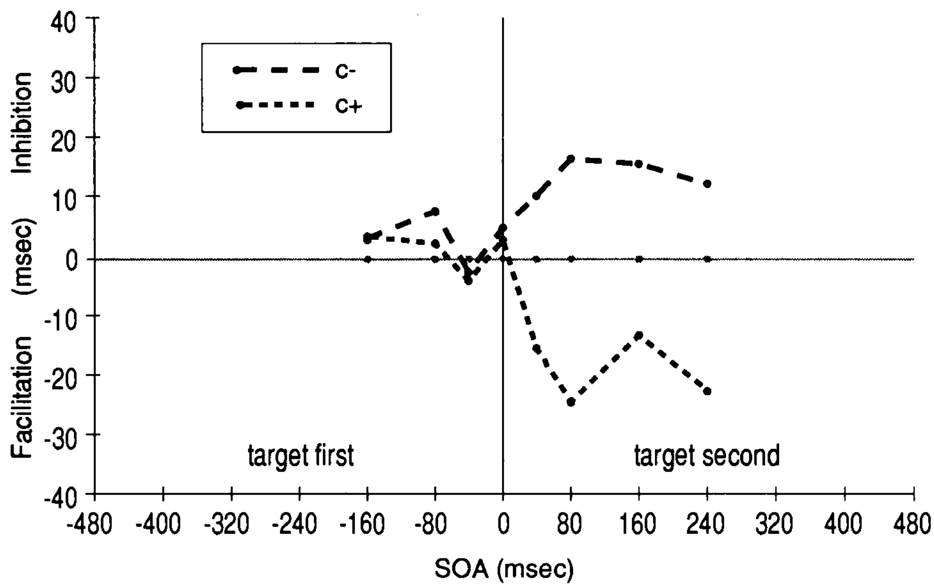


FIGURE A4.8. RESPONSE TIMES (Experiment 1): The difference in mean response times in relation to neutral priming for ten additional subjects over the SOA-range -160 to +240 msec.

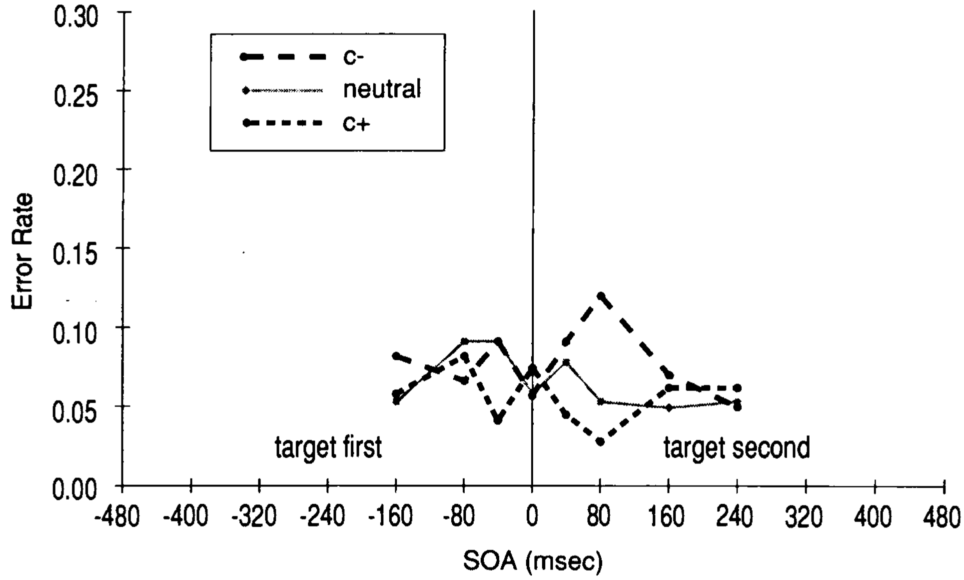


FIGURE A4.9. ERRORS (Experiment 1): The variation in error rate for ten additional subjects obtained over the SOA-range -160 to +240 msec.

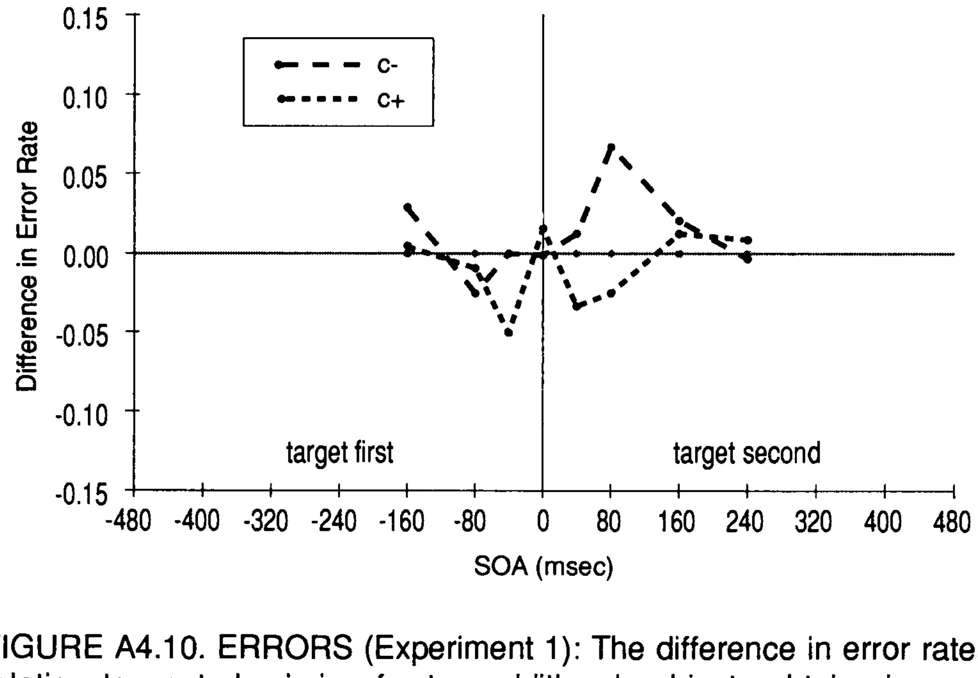


FIGURE A4.10. ERRORS (Experiment 1): The difference in error rates in relation to neutral priming for ten additional subjects obtained over the SOA-range -160 to +240 msec.

EXPERIMENT 2: Name-Priming of Name-Decision

Subjects: Three undergraduates and seven postgraduates served as unpaid volunteers.

Total number of responses: 5760
Number of responses falling below 200 msec limit: 6
Number of responses falling above 1000 msec limit: 39
Number of errors: 332

For SOA range -160 to +240 msec:
Main effect for SOA: $F(7,5359)=16.19$, $p<.001$
Congruency effect: $F(2,5359)=24.70$, $p<.001$
SOA/Congruency Interaction: $F(14,5359)=4.83$, $p>.001$

For SOA range -160 to -40 msec (post-exposed primes):
Main effect for SOA: $F(2,2029)=9.47$, $p<.001$
Congruency effect: $F(2,2029)=0.90$, $p>.001$
SOA/Congruency Interaction: $F(4,2029)=0.42$, $p>.001$

For SOA range +40 to +240 msec (pre-exposed primes):
Main effect for SOA: $F(3,2643)=7.92$, $p<.001$
Congruency effect: $F(2,2643)=51.00$, $p<.001$
SOA/Congruency Interaction: $F(6,2643)=0.91$, $p>.001$

Congruency effects for individual SOAs (*p<.05):

		Q(n+/N)	Q(n-/N)	Q(n+/n-)	χ^2(errors)
-160	F(2,684)=0.70				1.51
-80	F(2,677)=0.66				7.60*
-40	F(2,668)=0.43				1.27
0	F(2,687)=0.17				2.50
+40	F(2,655)=13.51*	3.33*	4.10*	7.43*	44.71*
+80	F(2,652)=13.49*	4.29*	3.09*	7.37*	58.26*
+160	F(2,658)=18.81*	5.41*	3.15*	8.56*	14.63*
+240	F(2,678)=6.51*	1.84	3.22*	5.06*	6.99*

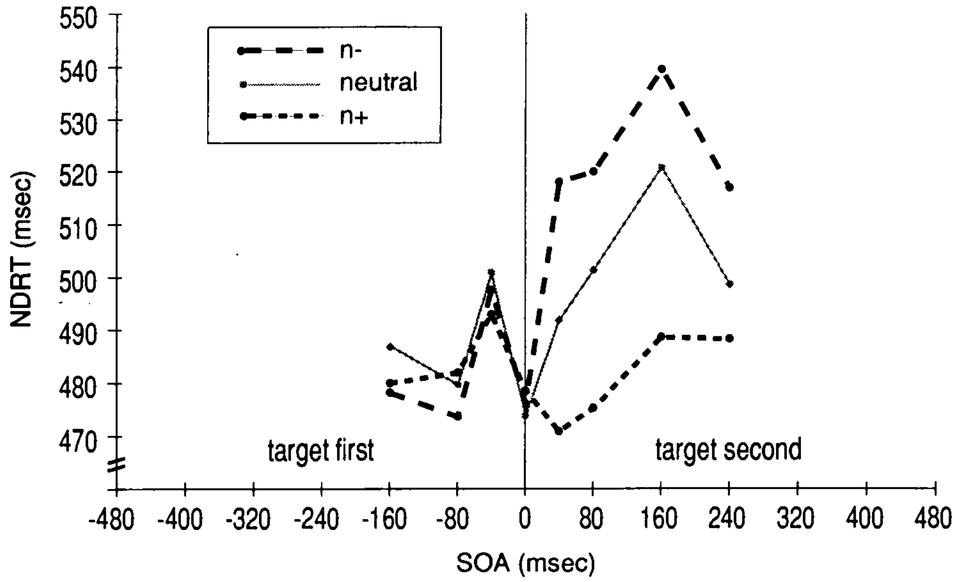


FIGURE A4.11. RESPONSE TIMES (Experiment 2): Mean correct name-decision response times for ten additional subjects over the SOA-range -160 to +240 msec. Each mean is based on 288 trials.

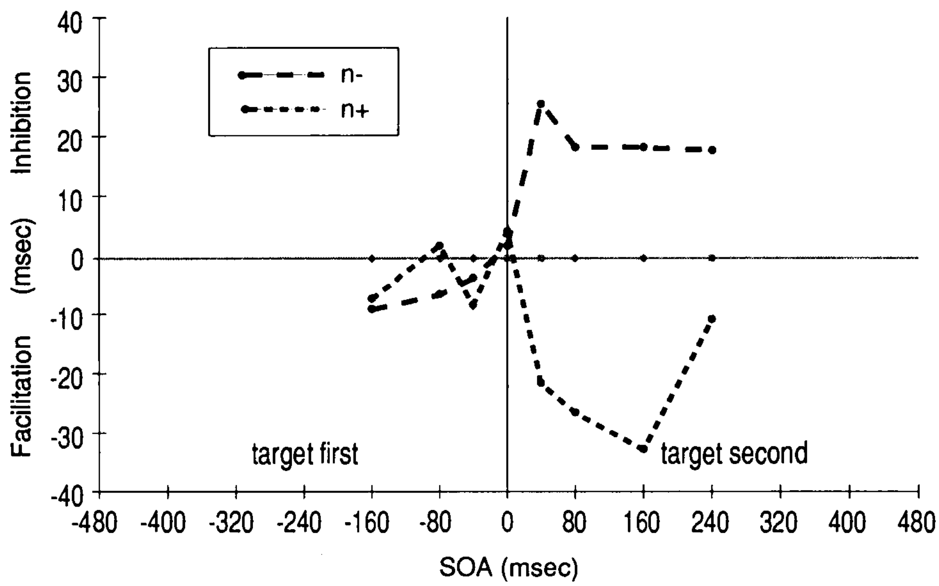


FIGURE A4.12. RESPONSE TIMES (Experiment 2): The difference in mean response times in relation to neutral priming for ten additional subjects over the SOA-range -160 to +240 msec.

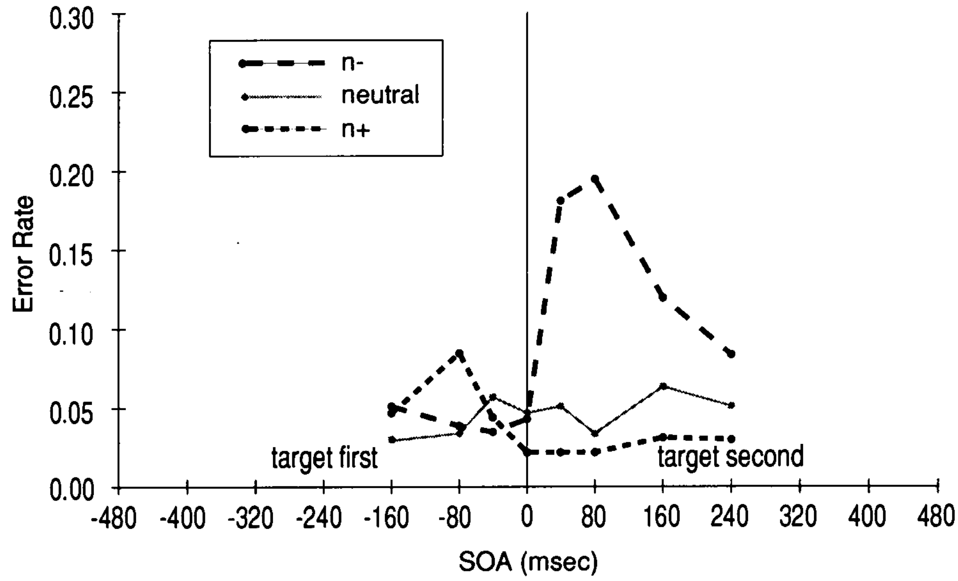


FIGURE A4.13. ERRORS (Experiment 2): The variation of error rate for ten additional subjects obtained over the SOA-range -160 to +240 msec.

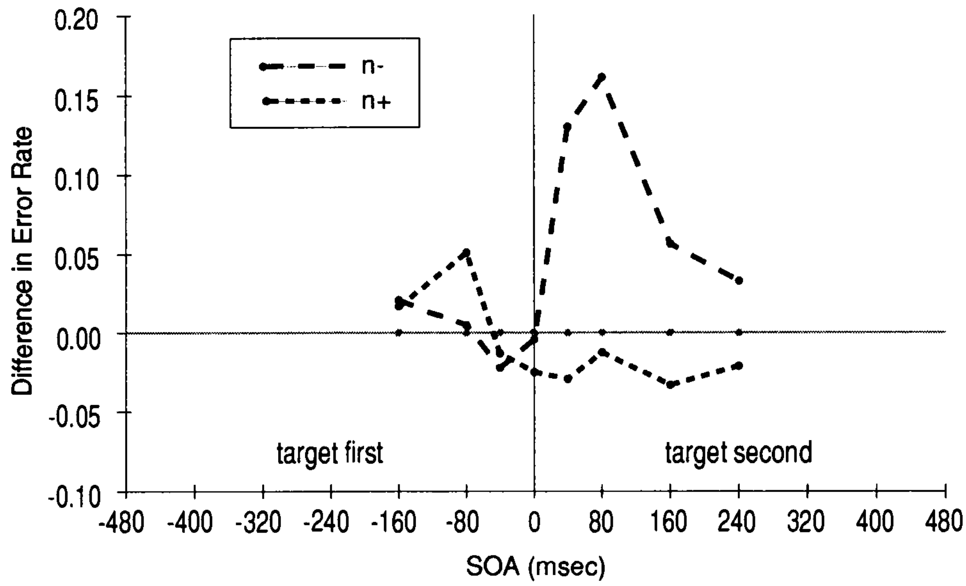


FIGURE A4.14. ERROR RATES (Experiment 2): The difference in error rates in relation to neutral priming for ten additional subjects over the SOA-range -160 to +240 msec.

EXPERIMENT 3: Name-Priming of Case-Decision

Subjects: Two undergraduates and eight postgraduates served as unpaid volunteers.

Total number of responses: 5760
Number of responses falling below 200 msec limit: 1
Number of responses falling above 1000 msec limit: 14
Number of errors: 514

For SOA range -160 to +240 msec:
Main effect for SOA: $F(7,5207)=10.79$, $p<.001$
Congruency effect: $F(2,5207)=7.99$, $p<.001$
SOA/Congruency Interaction: $F(14,5207)=1.60$, $p>.001$

For SOA range -160 to -40 msec (post-exposed primes):
Main effect for SOA: $F(2,1999)=0.37$, $p>.001$
Congruency effect: $F(2,1999)=0.32$, $p>.001$
SOA/Congruency Interaction: $F(4,1999)=0.24$, $p>.001$

For SOA range +40 to +240 msec (pre-exposed primes):
Main effect for SOA: $F(3,2553)=7.37$, $p<.001$
Congruency effect: $F(2,2553)=10.78$, $p<.001$
SOA/Congruency Interaction: $F(6,2553)=1.65$, $p>.001$

Congruency effects for individual SOAs ($^*p<.05$):

		Q(n+/N)	Q(n-/N)	Q(n+/n-)	χ^2(errors)
-160	F(2,668)=0.34				0.57
-80	F(2,670)=0.37				0.88
-40	F(2,661)=0.10				2.83
0	F(2,655)=0.01				2.25
+40	F(2,618)=0.11				36.88*
+80	F(2,634)=1.59				20.45*
+160	F(2,646)=9.14*	2.61	3.39*	5.99*	6.78*
+240	F(2,678)=6.51*	3.38*	3.10*	6.48*	6.18*

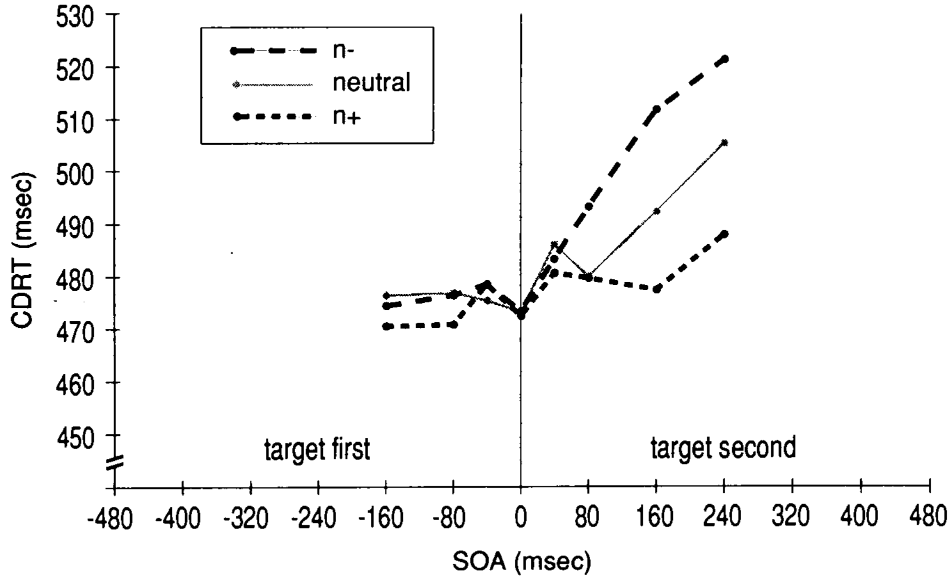


FIGURE A4.16. RESPONSE TIMES (Experiment 3): Mean correct case-decision response times for ten additional subjects over the SOA-range -160 to +240 msec. Each mean is based on 288 trials.

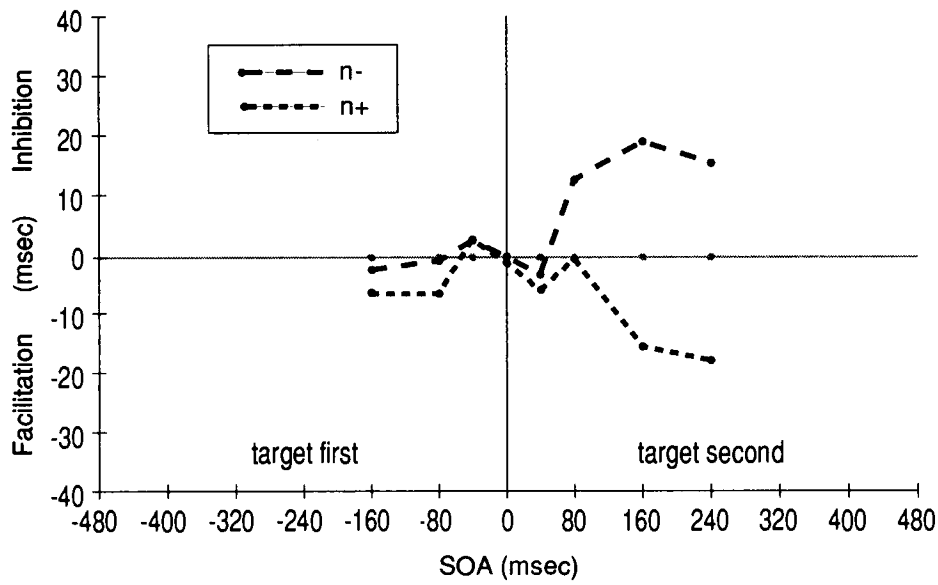


FIGURE A4.17. RESPONSE TIMES (Experiment 3): The difference in mean response times in relation to neutral priming for ten additional subjects over the SOA-range -160 to +240 msec.

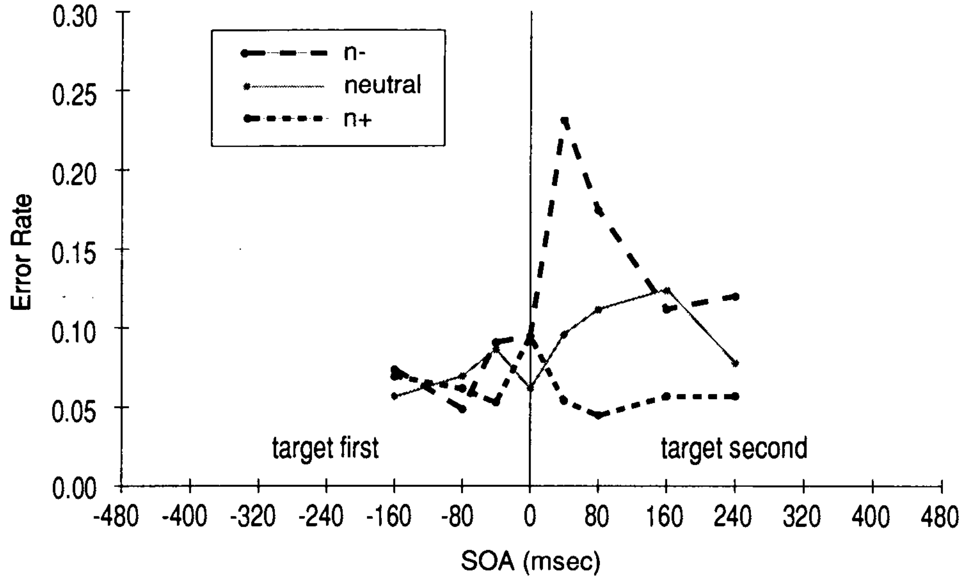


FIGURE A4.18. ERRORS (Experiment 3): The variation of error rate for ten additional subjects obtained over the SOA-range -160 to +240 msec.

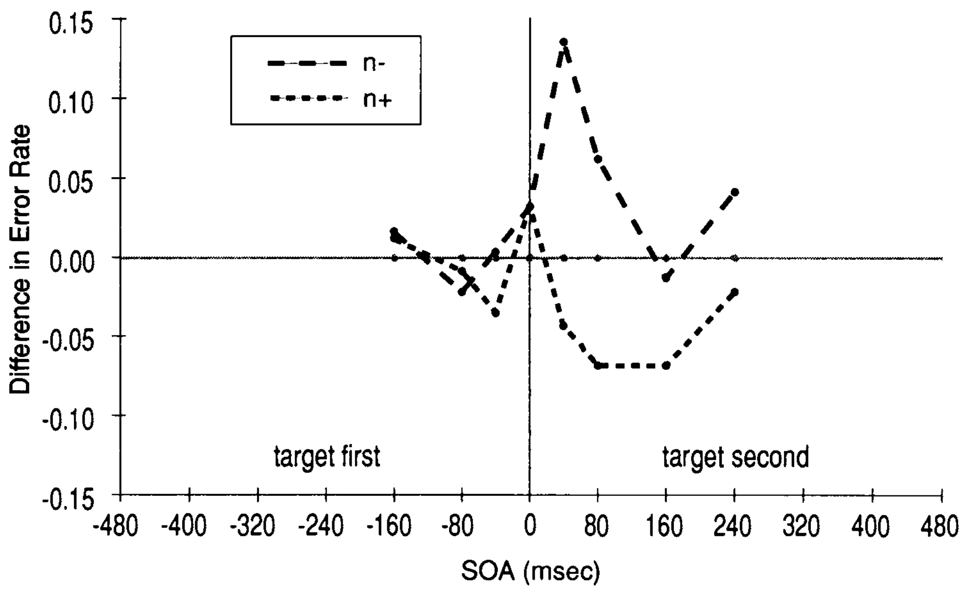


FIGURE A4.19. ERROR RATES (Experiment 3): The difference in error rates in relation to neutral priming for ten additional subjects over the SOA-range -160 to +240 msec.

EXPERIMENT 4: Case- and Name-Priming of Case-Decision

Subjects: Two undergraduates and twelve postgraduates served as unpaid volunteers.

Total number of responses: 15680
Number of responses falling below 200 msec limit: 19
Number of responses falling above 1000 msec limit: 39
Number of errors: 1160

<u>For SOA range -160 to +240 msec</u>:
Main effect for SOA: $F(7,14406)=16.17$, $p<.001$
Congruency effect: $F(6,14406)=12.59$, $p<.001$
SOA/Congruency Interaction: $F(42,14406)=1.85$, $p>.001$

<u>For SOA range -160 to -40 msec (post-exposed primes)</u>:
Main effect for SOA: $F(2,5467)=4.61$, $p>.001$
Congruency effect: $F(6,5467)=0.98$, $p>.001$
SOA/Congruency Interaction: $F(12,5467)=1.33$, $p>.001$

<u>For SOA range +40 to +240 msec (pre-exposed primes)</u>:
Main effect for SOA: $F(3,7154)=22.19$, $p<.001$
Congruency effect: $F(6,7154)=26.66$, $p<.001$
SOA/Congruency Interaction: $F(18,7154)=0.81$, $p>.001$

For c+/N	$Q(7175)=5.48$	$p<.05$
For c-/N	$Q(7175)=3.50$	$p<.05$
For c+/c-	$Q(7175)=8.98$	$p<.05$
For c+n+/c+	$Q(7175)=2.36$	$p>.05$
For c+n-/c+	$Q(7175)=4.07$	$p<.05$
For c+n+/c+n-	$Q(7175)=6.43$	$p<.05$
For c-n+/c-	$Q(7175)=1.63$	$p>.05$
For c-n-/c-	$Q(7175)=$ n/a	($p>.05$)
For c-n+/c-n-	$Q(7175)=2.05$	$p>.05$

Congruency effects for individual SOAs (*p<.05):

		Q(c+/N)	Q(c-/N)	Q(c+/c-)
-160	F(6,1835)=0.82			
-80	F(6,1804)=0.65			
-40	F(6,1828)=1.01			
0	F(6,1785)=0.58			
+40	F(6,1760)=6.45*	2.71	1.35	4.06*
+80	F(6,1763)=8.49*	3.12	3.42*	6.54*
+160	F(6,1804)=4.55*	3.02	1.77	4.79*
+240	F(6,1827)=2.87*	2.05	0.49	2.54

	Q(c+n+/c+)	Q(c+n-/c+)	Q(c+n+/c+n-)
-160			
-80			
-40			
0			
+40	1.15	1.07	2.22
+80	1.23	2.16	3.39*
+160	0.92	2.31	3.22
+240	1.42	2.62	4.04*

	Q(c-n+/c-)	Q(c-n-/c-)	Q(c-n+/c-n-)	χ^2(errors)
-160				3.73
-80				5.65
-40				8.14
0				8.75
+40	0.58	1.58	1.00	47.33*
+80	2.33	0.46	1.87	56.73*
+160	1.37	0.67	0.69	13.02*
+240	0.06	0.56	0.50	21.41*

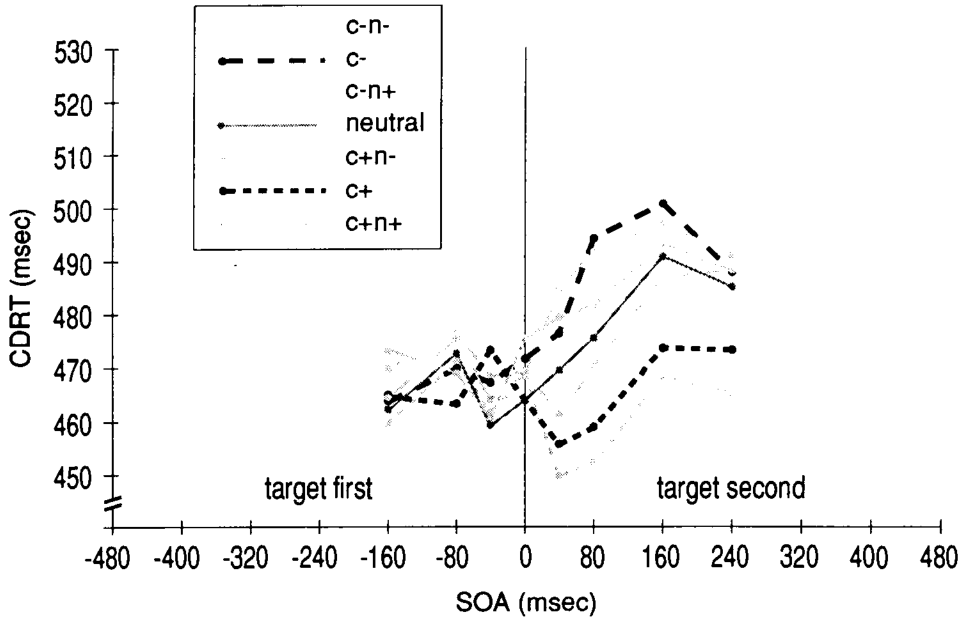


FIGURE A4.26. RESPONSE TIMES (Experiment 4): Mean correct case-decision response times for fourteen additional subjects over the SOA-range -160 to +240 msec. Each mean is based on 280 trials.

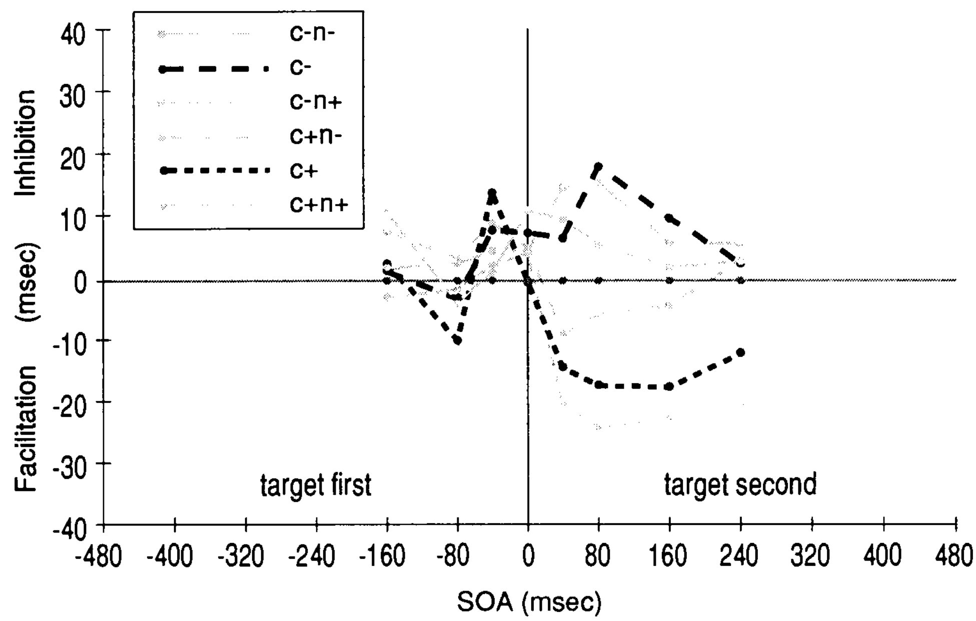


FIGURE A4.27. RESPONSE TIMES (Experiment 4): The difference in mean response times in relation to neutral priming for fourteen additional subjects over the SOA-range -160 to +240 msec.

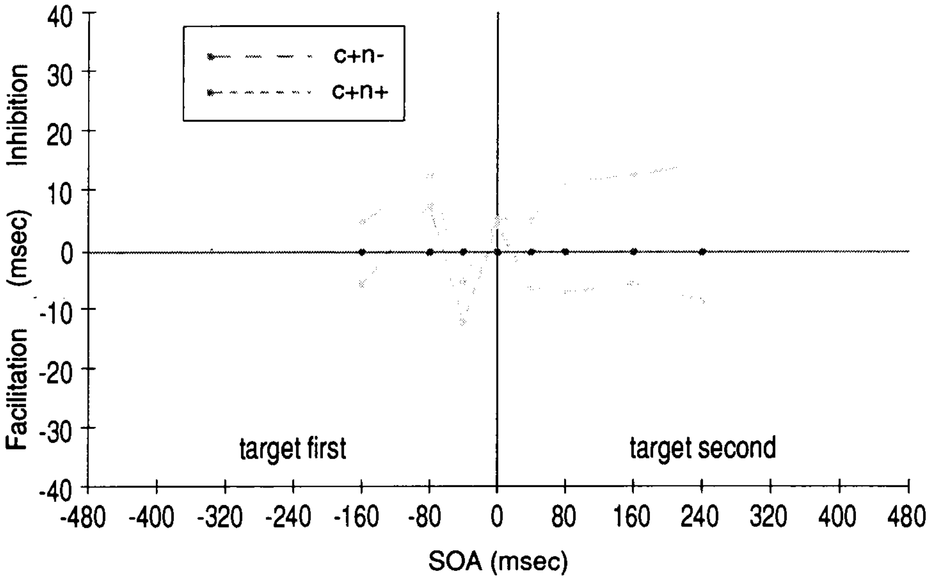


FIGURE A4.29. RESPONSE TIMES (Experiment 4): The difference in mean response times in relation to case-congruent priming for fourteen additional subjects over the SOA-range -160 to +240 msec.

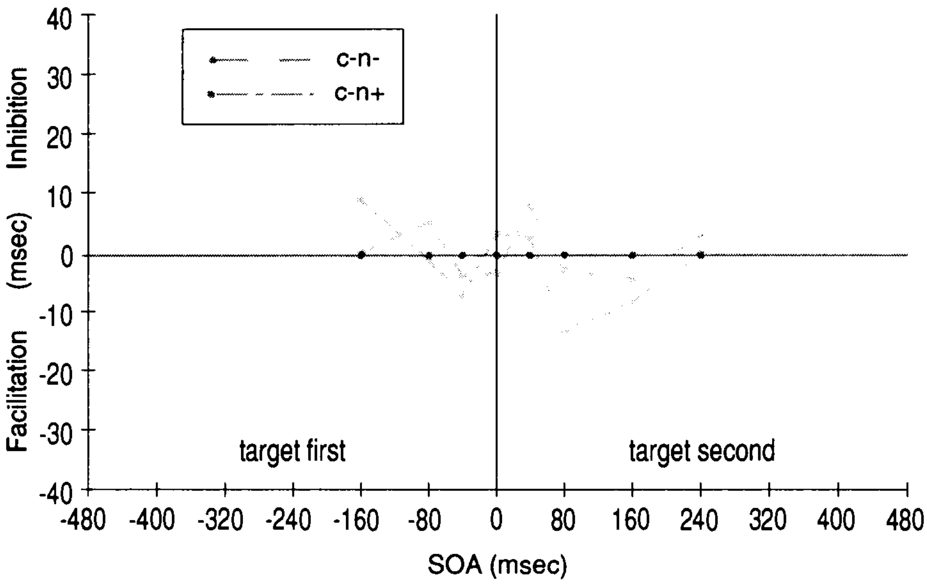


FIGURE A4.30. RESPONSE TIMES (Experiment 4): The difference in mean response times in relation to case-incongruent priming for fourteen additional subjects over the SOA-range -160 to +240 msec.

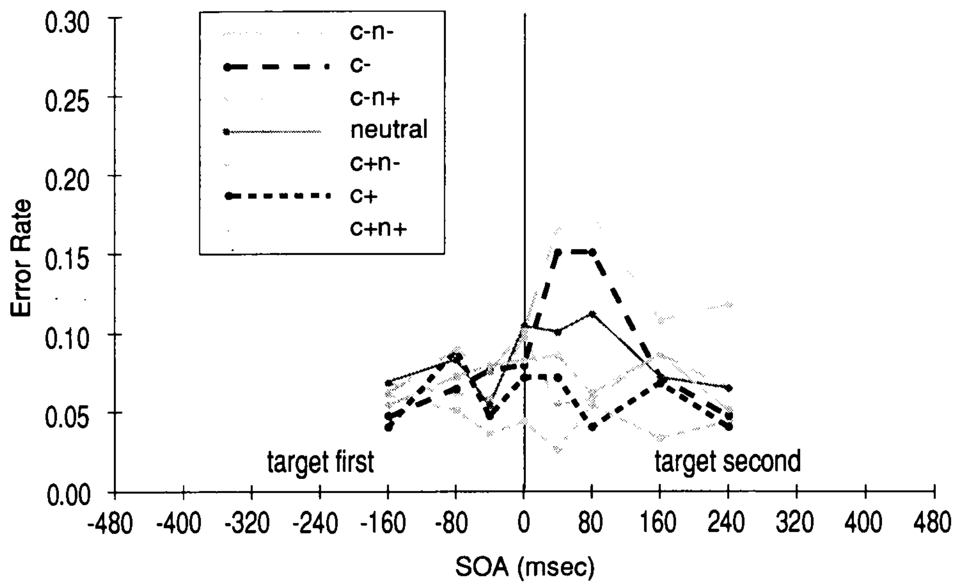


FIGURE A4.31. ERRORS (Experiment 4): The variation of error rate for fourteen additional subjects obtained over the SOA-range -160 to +240 msec.

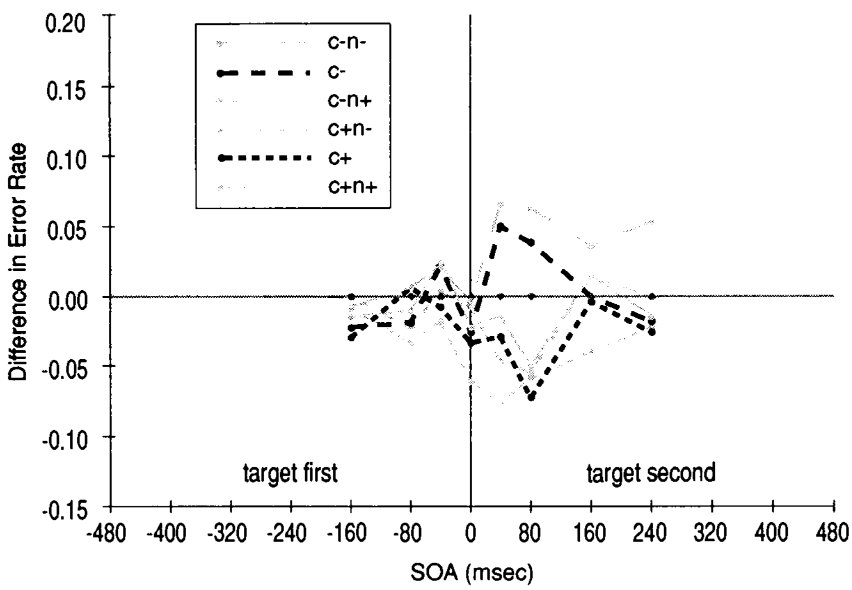


FIGURE A4.32. ERROR RATES (Experiment 4): The difference in error rates in relation to neutral priming for fourteen additional subjects over the SOA-range -160 to +240 msec.

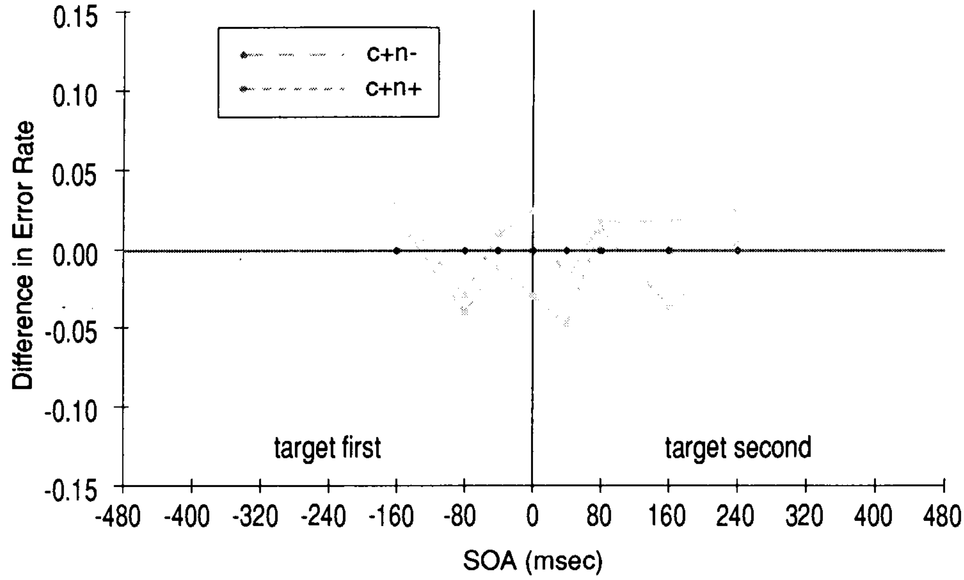


FIGURE A4.33. ERROR RATES (Experiment 4): The difference in error rates in relation to neutral priming for fourteen additional subjects over the SOA-range -160 to +240 msec.

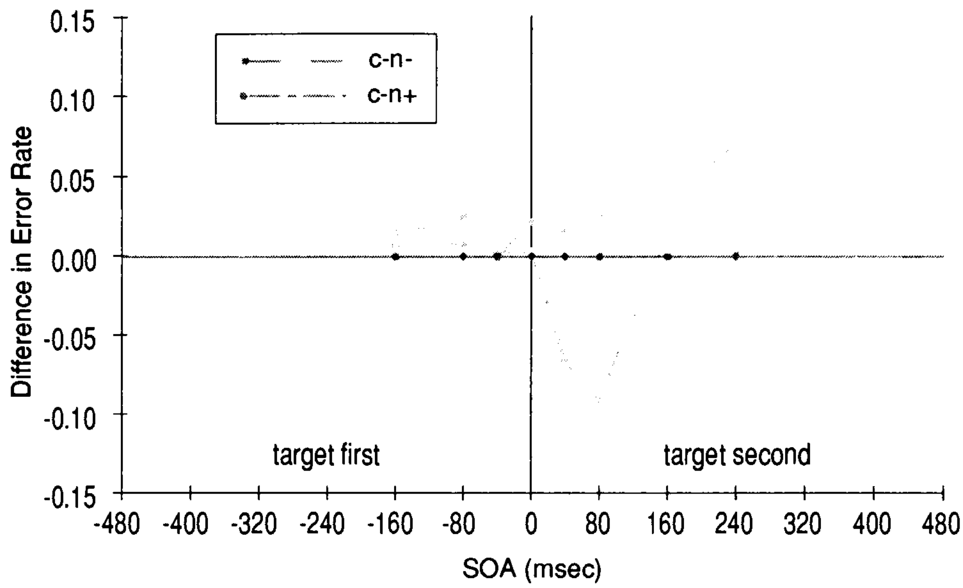


FIGURE A4.34. ERROR RATES (Experiment 4): The difference in error rates in relation to neutral priming for fourteen additional subjects over the SOA-range -160 to +240 msec.

EXPERIMENT 5: Case-Priming of Name-Decision

Subjects: Three undergraduates and seven postgraduates served as unpaid volunteers.

Total number of responses: 5760
Number of responses falling below 200 msec limit: 2
Number of responses falling above 1000 msec limit: 4
Number of errors: 372

For SOA range -160 to +240 msec:
Main effect for SOA: $F(7,5358)=6.78$, $p<.001$
Congruency effect: $F(2,5358)=11.90$, $p<.001$
SOA/Congruency Interaction: $F(14,5358)=1.17$, $p>.001$

For SOA range -160 to -40 msec (post-exposed primes):
Main effect for SOA: $F(2,2019)=21.56$, $p<.001$
Congruency effect: $F(2,2019)=0.08$, $p>.001$
SOA/Congruency Interaction: $F(4,2019)=0.51$, $p>.001$

For SOA range +40 to +240 msec (pre-exposed primes):
Main effect for SOA: $F(3,2682)=2.55$, $p>.001$
Congruency effect: $F(2,2682)=16.34$, $p<.001$
SOA/Congruency Interaction: $F(6,2682)=0.45$, $p>.001$

Congruency effects for individual SOAs (*p<.05):

		Q(c+/N)	Q(c-/N)	Q(c+/c-)	χ^2(errors)
-160	F(2,675)=0.54				0.15
-80	F(2,671)=0.04				2.42
-40	F(2,673)=0.64				4.70
0	F(2,657)=1.07				0.72
+40	F(2,673)=3.30*	3.03*	3.22*	0.19	3.82
+80	F(2,667)=4.16*	3.07*	3.86*	0.79	1.20
+160	F(2,669)=5.87*	4.47*	3.87*	0.60	0.13
+240	F(2,673)=4.48*	4.24*	2.18	2.07	1.52

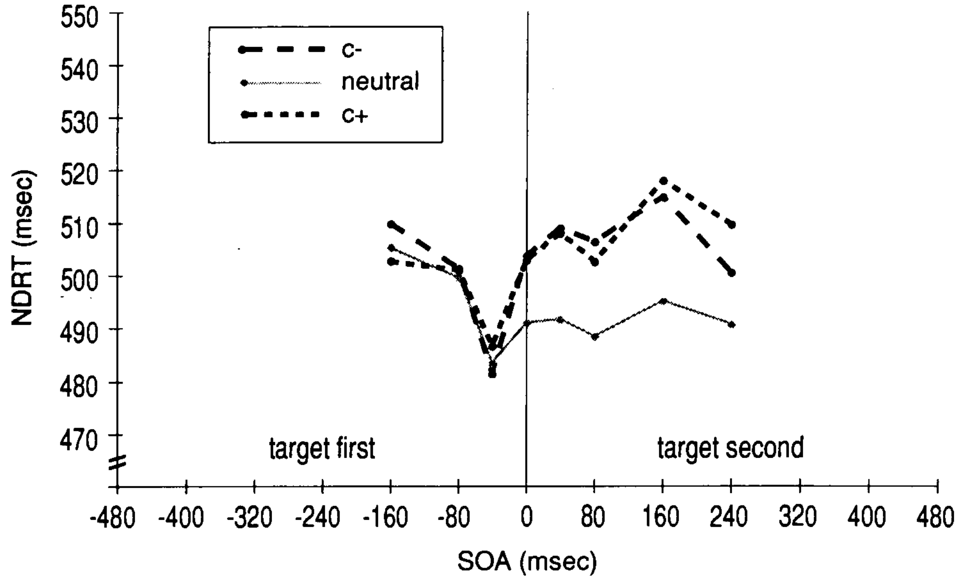


FIGURE A4.35. RESPONSE TIMES (Experiment 5): Mean correct name-decision response times for ten additional subjects over the SOA-range -160 to +240 msec. Each mean is based on 288 trials.

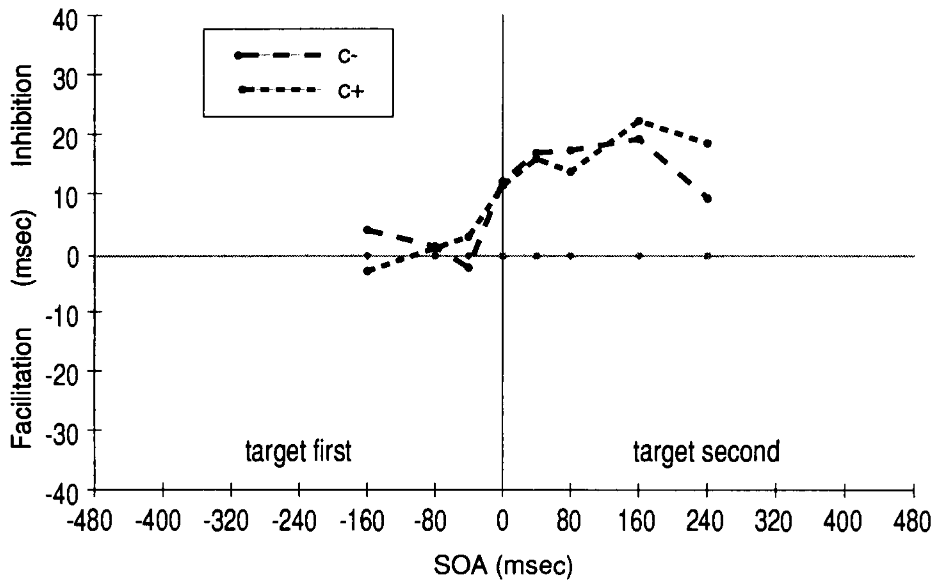


FIGURE A4.36. RESPONSE TIMES (Experiment 5): The difference in mean response times in relation to neutral priming for ten additional subjects over the SOA-range -160 to +240 msec.

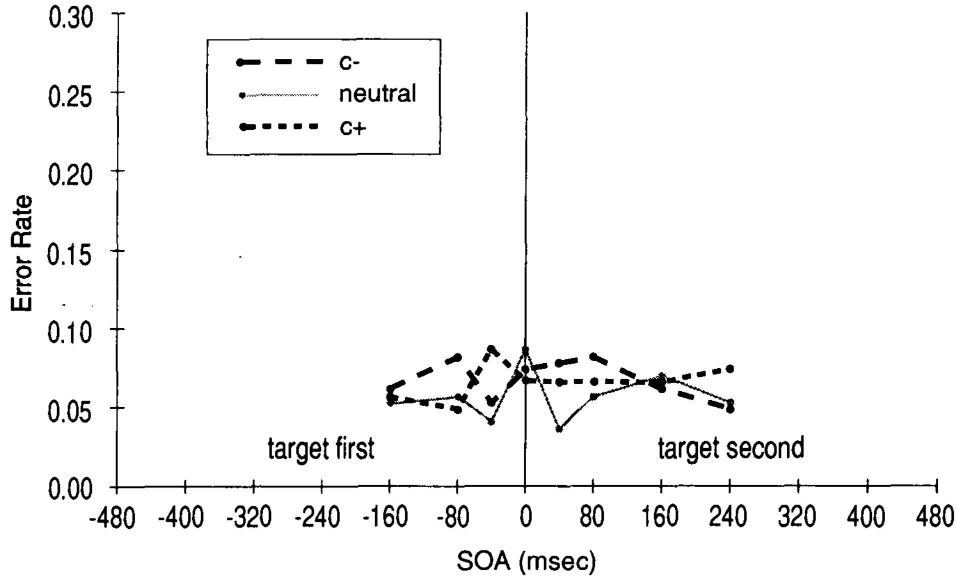


FIGURE A4.37. ERRORS (Experiment 5): The variation of error rate for ten additional subjects obtained over the SOA-range -160 to +240 msec.

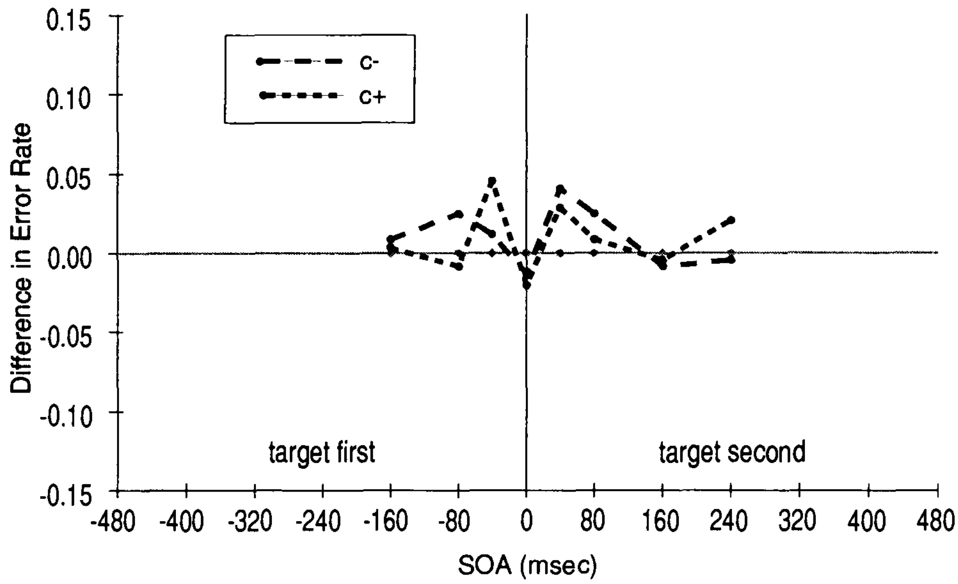


FIGURE A4.38. ERROR RATES (Experiment 5): The difference in error rates in relation to neutral priming for ten additional subjects over the SOA-range -160 to +240 msec.

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