Ageing and Implicit Learning: Explorations in Contextual Cuing

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Thesis Declaration

I, Andrea Smyth confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Signed:____

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Abstract

Research in cognitive ageing has found that while older adults show reductions in performance on standard explicit memory tasks, implicit memory performance remains relatively stable. Such findings are often used to support the popular dual-systems account of human learning and memory, which organizes these types of cognition into distinct implicit and explicit systems. In contrast to previous studies, we found that healthy older adults show learning impairments on an implicit contextual cuing task when compared to younger adults, in addition to expected poor performance on an explicit generation test. To examine the possibility that slower overall response speed may account for the implicit deficit, younger adults' response times were artificially increased by altering the display properties so as to match those of older adults. Learning in younger participants remained intact under these conditions. Similarly, when display properties were altered to produce faster responses in older participants, their learning continued to be impaired. These results reveal that implicit processing is not immune to the effects of ageing, and that these deficits cannot be attributed solely to older adults' slower overall response speed.

In a further series of experiments using younger participants, we examined the claim that implicit knowledge is not accessible to awareness in contextual cuing. When the number of trials used in an explicit generation test was increased, we found that contextual cuing information was consciously retrievable. These results suggest that the shorter tests used previously were not statistically powerful enough to detect a true effect. Furthermore, when concurrent implicit and explicit tests were used, learning did not precede awareness. Collectively, these findings suggest that awareness may be a necessary concomitant of

contextual cuing in older adults, and provide further evidence that learning and memory should not be divided on the basis of consciousness.

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This thesis is dedicated to the memories of my grandparents, Norma and Delton Smyth

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1 Ageing and Implicit Learning

With the proportion of the global population over the age of 65 expected to increase from 8% in 2008 to 24% by 2050 (U.S. Census Bureau, 2004) it comes as no surprise that scientific focus has become heavily concentrated on providing a clear picture of how the mind succumbs to the effects of time. Although the prevention of more obvious physical hallmarks of getting older like impaired hearing, vision, and motor skills have always been a concern, the increased prevalence of debilitating neurological diseases like Alzheimer's disease and Mild Cognitive Impairment have made memory loss one of the most prominent topics in ageing research. Research has shown that even the healthiest older adults show reductions in performance on tasks of attentional capacity (Levitt, Fugelsang, & Crossley, 2006), working memory (Fristoe, Salthouse, & Woodward, 1997; Hasher & Zacks, 1988; Salthouse & Prill, 1987; Salthouse, Mitchell, Skovronek, & Babcock, 1989) and episodic memory (Balota, Dolan, & Duchek, 2000; Spencer & Raz, 1995) in relation to younger adults. In contrast, it has been suggested that performance on tests of implicit memory, such as repetition priming (Light & Singh, 1987; Light, La Voie, & Kennison, 1995; Moscovitch, 1982; Prull, 2004), word-stem completion (Dick, Kean, & Sands, 1989; Jelicic, Craik, & Moscovitch, 1996; Light & Singh, 1987; Mitchell & Bruss, 2003), and artificial grammar learning (McGeorge, Crawford, & Kelly, 1997; Midford & Kirsner, 2005), remains relatively stable with age. This has led some theorists to the striking hypothesis that implicit processing is immune to the effects of cognitive ageing (Fleischman & Gabrieli, 1998; Fleischman Gabrieli, Wilson, Moro, & Bennett, 2005; Java

& Gardiner, 1991; Light, Singh, & Capps, 1986; Mitchell & Bruss, 2003; Prull, Gabrieli, & Bunge, 2000).

In addition to providing optimistic views of aspects of ageing and cognition, findings of spared implicit memory in older adults have also been used to validate the popular dual-systems account of human learning and memory, which organizes these types of cognition on the basis of consciousness. According to the dual-systems framework, the implicit system not only processes information unintentionally and automatically, i.e., in the absence of strategy or motivation and outside the bounds of attentional allocation; but more intriguingly, also operates independent from, and processes content that is not accessible to, conscious awareness (Squire, 1992). Therefore, results of intact implicit processing despite explicit memory impairments in healthy older populations are seen as crucial experimental evidence, akin to the dissociations obtained in amnesic patient populations, for the existence of separate implicit and explicit memory systems.

Yet some scepticism has arisen of both results of amnesic memory dissociations (Kinder & Shanks, 2001; 2003; Ostergaard, 1999; Reder, Park, & Kieffaber, 2009; Shanks, Channon, Wilkinson, & Curran, 2006) and findings of age-related invariance on implicit tasks (Rybash, 1996; Salthouse, McGuthry, & Zambrick 1999), which suggest that these results may not necessarily reflect spared implicit abilities in either of these populations. Claims of a pure and resilient implicit processing system (Daselaar, Rombouts, Veltman, Raaijmakers, & Jonker, 2003; Luo & Craik, 2008; Prull et al., 2000; Reber, 1992) break down even further when we consider that many re-examinations of these findings have been unable to replicate original results of spared implicit memory in older adults

(Chiarello & Hoyer, 1988; Curran 1997; Fleischman et al., 2005; Howard, 1988; Howard & Howard, 1997; Hultsch, Masson, & Small, 1991; La Voie & Light, 1994).

Howard, Howard, Dennis, and Yancovich (2004) compared healthy older and younger adults' performance on an implicit sequence learning paradigm proposed by Nissen and Bullemer (1987) called the Serial Reaction Time task (SRT). Howard et al. (2004) found evidence to suggest that older adults did not perform at the same level as younger adults in the SRT task. Yet the authors attributed this result to the questionable purity of the implicit processing driven by the SRT task, while maintaining that results of equivalent implicit performance in the same older and younger participants using a contextual cuing task (Chun & Jiang, 1998) reflected the true stability of implicit memory in an ageing population. This conclusion is encouraging in the context of the negative outlook usually associated with cognitive ageing; however, it may not be entirely accurate given that the performance dissociation that is critical to this claim becomes questionable when age-constancy in contextual cuing is examined in more detail. This thesis will critically evaluate the conclusion of Howard et al. (2004), that contextual cuing is immune to the effects of cognitive ageing, by examining age-related differences in the onset of learning, response speed, and explicit memory in contextual cuing.

1.1 Known Effects of Cognitive Ageing

When exactly does cognitive decline begin? Early longitudinal examinations of cognitive functioning by Thorndike, Bergman, Tilton, and Woodyard (1928) and Jones and Conrad (1933) argued that our mental faculties actually improved into middle-age, and the onset of mental debilitation was both sudden and very late in life (Salthouse, 2009). The recent advent of neuroimageing techniques have been invaluable in allowing psychology to connect the noticeable behavioural consequences of ageing with in vivo age-related changes to the structural integrity and architecture of the brain. Subsequent evidence from functional neuroimageing and behavioural studies presents the occurrence of neural deterioration and lower mental capacity on a continuum, rather than occurring suddenly as previously thought, which begins in early adulthood but declines much more steeply after the age of 50 (Dennis & Cabeza, 2008; Raz, 2005; Raz & Rodrigue, 2006). These changes make many aspects of information processing difficult, including lower working memory capacity, impaired episodic memory, and slower processing speed in older adults. In contrast, other aspects of cognitive functioning like implicit memory have been thought of as resistant to these changes (Schacter, Valdiserri, & Cooper, 1992).

1.1.1 Slower Processing Speed

Although volumetric shrinkage rates in the cerebral cortex as a whole are of common interest, at 0.12% and 0.35% per year for younger and older adults respectively (Raz, 2005), white matter health in the ageing brain is also a relevant concern. Even in healthy older adults, the structural integrity of white matter in the brain significantly declines to form what are known as white matter hyperintensities (WMH). The frontal and occipital lobes see the largest increase in WMH volume in the brain (Brickman et al. 2005; DeCarli et al, 1995; Raz et al., 1997; Tisserand et al. 2002). The main implications of WMH are demyelination, (the breakdown of the myelin sheath that helps efficient transmission of neural signals) (Meier-Ruge, Ulrich, Brühlmann, & Meier, 1992), and myelin redundancy (a response of increased myelin production to compensate for myelin breakdown that results in malformed splitting tissue) (Peters, Sethares, & Killiany, 2001).

Both of these processes have a deleterious effect on signal conduction, translating behaviourally into slower neural signal transmission.

An obvious consequence of this lag in neural processing, known as cognitive slowing, is the consistently slower response times of older adults on speeded tasks. Some research has implicated inefficient signal transmission as preventing new associations from forming (MacKay & Burke, 1990), or as the cause of retrieval failures, which lead to tip of the tongue occurrences (Brown & Nix, 1996), and increased incidences of false memory (Chan & McDermott, 2007) in older adults. Most notably, Processing-Speed Theory (Salthouse, 1985; 1996) seeks to account for most age-related declines in cognitive functioning in terms of cognitive slowing.

Processing-Speed Theory is dominated by this central concept: the slower rate of processing in older adults constrains the quantity of knowledge that can be encoded, leading to lower quality informational traces, and ultimately, age-related performance impairments on a range of cognitive tasks. A further two main principles delineate exactly how cognitive slowing inhibits information intake. The first, known as the *limited time mechanism*, supposes that when processing speed is diminished, the execution of early basic cognitive operations takes longer, leaving less time available for the completion of later operations, and resulting in an incomplete representation of the relevant information. According to the second principle, the *simultaneity mechanism*, longer execution of operations not only creates greater demand for the simultaneous preservation of products of earlier operations and relevant peripheral information from decay as a function of time; but also, makes it more difficult to perform tasks concurrently. Ultimately, this results in the loss or degradation of earlier information by the time later processing has finished.

This view is supported by evidence that processing speed declines steadily with age. An early study of this phenomenon by Miles (1931) measured participants' speed in detecting a buzzing sound using a morse key, and observed pronounced slowness in participants over 60 years old. Since then, studies have become more sophisticated in measuring this construct, but have consistently replicated this finding (Birren & Botwinick, 1955; Birren & Morrison, 1961; Cerella, 1985; Craik & Rabinowitz, 1985; Eriksen, Hamlin, & Daye, 1973; Fisk & Rogers, 1991; Griew, 1959; Hasher & Zacks, 1979; Rabbitt, 1964; Salthouse, 1978; 1980; Simon, 1968).

Structural equation modelling (Salthouse, 2001) and similar statistical techniques provide further support for the idea by showing that processing speed is a consistently strong mediator of cognitive decline. Standardised measures of processing speed include the digit symbol substitution task, a simple exercise requiring participants to use a pre-determined code of symbols to digits to fill in a worksheet containing only digits with the appropriate symbols as rapidly as possible. To examine the amount of attenuation in age-related variance for a given cognitive task when participants' processing speed has been statistically controlled for, many studies have related low-level measures of processing speed to the performance of older adults on a variety of cognitive tasks (e.g., counting tasks, Sliwinski, 1997; Stroop, Uttl, & Graf, 1997; memory span, Cowan, Wood, Wood, Keller, Nugent, & Keller, 1997; Kail & Park, 1994; task switching, Salthouse, Fristoe, McGuthry, & Hambrick, 1998).

In particular, Fristoe et al. (1997) analysed age differences that resulted from performance on the Wisconsin Card Sorting Test (WCST) in relation to working memory and processing speed. Fristoe et al. were able to determine that older adults were not utilizing the feedback of responses in the task as effectively as younger adults. Interestingly, when perceptual speed measures were included in hierarchical regression analyses of working memory and feedback usage on WCST performance, controlling for all 3 variables resulted in 91.7% attenuation of age-related WCST performance differences. Further regressions revealed that differences in working memory and feedback usage in older and younger adults were mediated by corresponding differences in processing speed. The parsimony of the processing speed argument has great appeal, in that it replaces earlier more task-specific theories of age-related impairments with a simple single mechanism approach to cognitive ageing.

1.1.2 Explicit Memory Impairments

Another by-product of growing older is memory decline. Older people experience difficulties on episodic memory tasks (McIntyre & Craik, 1987; Schacter, Kaszniak, Kihlstrom, & Valdiserri, 1991), which involve remembering specific autobiographical events and often contain a spatial and temporal context. Working memory, also known as short-term memory, is the ability to temporarily retain relevant knowledge for later use. Older people also show much lower working memory capacity in comparison to younger adults (Craik & Jennings, 1992; Dobbs & Rule, 1989; Hartman, Bolton, & Fehnel, 2001; Salthouse & Babcock, 1991). Episodic and working memory are mediated by explicit processing, since information contained in both of these memory stores is intentionally acquired and consciously retrievable.

As described in the previous section, some accounts of cognitive ageing suppose that slower processing speed is the mechanism for these memory deficits; however, there are other arguments to suggest that a loss of inhibitory control (Hasher & Zacks, 1988), or declining sensory functioning (Lindenberger & Baltes, 1994) occurring with age may be additional or alternative explanations for age-related impairments.

Hasher and Zacks (1988) proposed that working memory capacity may not actually diminish in older adults; instead declines in performance in these tasks may be a consequence of an inefficient filtering mechanism. Therefore, older adults may still be able to retain the same quantity of information, but diminished inhibitory processes make the contents of their working memory stores particularly susceptible to irrelevant information. This “mental clutter” interferes with processing of relevant information, and ultimately leads to cognitive failures and slower responding on memory tasks (Zacks, Hasher, & Li, 2000). Studies using the Stroop task (Stroop, 1935), where inhibition of the word while naming the perceptual features is crucial to performance (i.e., the word “green” appearing in the colour blue), have shown that the magnitude of interference caused by irrelevant perceptual features is greater in older adults (Cohn, Dustman, & Bradford, 1984; Langenecker, Nielson, & Rao, 2004), and does not diminish with prolonged practice as it does in younger adults (Davidson, Zacks, & Williams, 2003). Perhaps the most convincing evidence of inhibitory decline, because it occurs with such a low-level response, are recent findings by Butler and Zacks (2006) showing that older adults were not as efficient at inhibiting prepotent eye movement responses to irrelevant peripheral distracter cues as younger adults.

In contrast, the Sensory Deficit Theory proposes a basic link between sensory functions and cognitive processing, suggesting that the loss of visual and auditory functioning that occurs with age has particularly deleterious effects on the intake of information (Lindenberger & Ghisletta, 2009). Using a similar approach to Salthouse

(1996) with processing speed, Lindenberger and Baltes (1994) have shown that strong relationships exist between visual and auditory acuity in older adults and their performance on a battery of cognitive tests, including several tests of explicit memory, and argue that these factors are more powerful predictors of performance than processing speed measures like the digital symbol substitution task.

1.2 The Implicit-Explicit Memory Distinction

There has been an accumulation of research over the past 30 or so years which appears to suggest that human learning and memory are organized into at least two distinct systems, one of which is explicit or declarative and one of which is implicit or procedural. The former system allows conscious recall of facts or events while the latter influences performance unconsciously (Squire, 1992). Central to this systems view of learning and memory is a very large body of evidence that the implicit system can be isolated in appropriate preparations: that is to say, in tasks where learning proceeds independently of the individual's awareness of the learned properties of the materials. Such 'implicit learning' tasks – which have been studied for many decades (Thorndike, 1931) – therefore have an important reciprocal relationship to memory systems theories.

Despite the enormous number of studies attempting to demonstrate implicit learning, it is fair to say that these have been consistently dogged by controversy. A common cycle of research begins with a new and apparently compelling instance of implicit learning, only for this instance to be undermined and challenged by later research. Examples include Thorndike's own studies of verbal operant conditioning (Dulany, 1961), Reber's artificial grammar experiments (Dulany, Carlson, & Dewey, 1984), learning in the

Iowa Gambling Task (Maia & McClelland, 2004), studies of human conditioning (Lovibond & Shanks, 2002), and studies of reaction times to sequentially-structured stimuli (Perruchet & Amorim, 1992).

1.2.1 Evidence from Tests of Awareness

Dual-systems theories of memory organization rely heavily on empirical evidence of dissociations between direct (explicit) and indirect (implicit) measures of knowledge. The rationale is that a purely implicit processing mechanism is demonstrated when the possession of knowledge is expressed on an indirect measure (such as RT), but the same knowledge is not consciously retrievable when assessed on a direct measure of learning (such as prediction, recognition).

Although superficially these results of dissociations between direct and indirect measures of learning seem to demonstrate that the dual-systems perspective is valid in its partitioning of memory according to awareness at learning, a number of methodological problems have been raised against previous dissociations of this sort (Shanks & St. John, 1994). Often when these problems are rectified, the finding of implicit learning without explicit access is not replicated (Shanks & Johnstone, 1999; Shanks & Perruchet, 2002).

One such issue relates to the power and reliability of the awareness test. The modal implicit learning finding is of above-chance performance on an indirect test such as contextual cuing, together with chance performance on an explicit test. Plainly, this means that the inference of implicit learning rests on a null result in the awareness test, and the interpretation of such a null result depends critically on that test's power and reliability. Yet these awareness tests are rarely set up in such a way as to guarantee adequate power/reliability. Although implicit measures are often made up of many hundreds of trials, awareness tests usually only contain a single presentation of learned stimuli. An 'awareness effect' would have to be very large to be reliably detected in such a small number of trials. This concern poses a problem to dual-systems arguments when one considers that null effects on explicit tests obtained by past experiments may merely be a product of using statistically weak measures, rather than a genuine illustration of a dissociation between implicit and explicit memory systems.

Additional criticisms outlined by Shanks and St. John (1994) of these behavioural dissociations between learning and awareness call further attention to the importance of experimental rigor in explicit tests. Namely, these authors proposed two requirements that experimenters should adhere to when designing awareness measures in order for results to be considered as valid evidence of a dual-systems theory of learning and memory.

First, a measure of awareness must be sensitive to all of the conscious information the participant has acquired in the task, i.e., the explicit test should be exhaustive (Shanks & St. John, 1994). Under this 'sensitivity criterion', measures of awareness based on verbal report are deemed unsuitable. Not only is it common for participants to be unable to verbalize knowledge of learned information (Reber, 1967), but the subjectivity of such a test of awareness may also make participants more likely to report only conscious information held with moderately high confidence (Kunimoto, Miller, & Pashler, 2001). When this is the case, dissociations between performance on an implicit task measuring RT and awareness measured using verbal report may be indicative of the insensitivity of the awareness test, rather than a true display that knowledge that is inaccessible to consciousness.

Second, Shanks and St. John (1994) proposed the 'information criterion', which says that measures of awareness should probe for the same information that supports performance on the implicit task. For instance, Greenspoon (1955) demonstrated that participants could be conditioned by the experimenter to produce a specific response, in this case plural nouns, when asked to randomly generate words. The positive reinforcement contingency used in this study was simply the experimenter saying 'umhmm' after a participant responded with a plural noun, and produced the desired outcome of a higher frequency of plural nouns in participants. This seemed to be a demonstration of learning without awareness, since participants who learned this association appeared to be unable to accurately report knowledge of this association between experimenter feedback and their own responses. However, a follow-up interpretation of this study by Dulany (1961) showed that Greenspoon was mistaken in only assigning awareness to participants who reported the contingency the experimenter implanted specifically. Another rule commonly reported by participants (following a word with another in the same semantic category would lead to reinforcement) also produced the desired pattern of saying a plural noun (apples) reliably followed by another plural noun response (bananas). Consequently, Dulany (1961) concluded that participants in Greenspoon (1955) actually did display conscious awareness of the rule that governed their implicit behaviour.

Another violation of the information criterion is evident in a demonstration of implicit sequence knowledge by Willingham, Nissen, and Bullemer (1989). In an SRT task a dot stimulus appears at 1 of 4 locations on the screen on each trial, and participants are asked to press a button corresponding to the location of dot on the screen as quickly as possible. Unbeknownst to participants, the locations of the dots across trials follow a predetermined 10-trial repeating sequence. Willingham et al. considered it an indication of learning the repeated sequence when participants' response times sped up with more exposure to the sequence, as well as in relation to participants trained on a random sequence. This knowledge was thought to be inaccessible to awareness, because participants were unable to accurately generate the learned sequence on the explicit test.

However, Shanks, Green, and Kolodny (1994) hypothesised that, since the probability of each dot location was not equal, participants' response efficiency might actually be mediated by learning the probability of a stimulus occurring at each location and not knowledge of the sequence. Shanks et al. confirmed this by replicating Willingham et al.'s result when a group of participants were trained on a pseudo-random sequence and the frequency of each stimulus location was matched to the repeated sequence.

The ideas described above outline circumstances in which obtained dissociations would provide strong evidence that learning and memory can be sufficiently partitioned into distinct implicit and explicit processing components.

1.2.2 Evidence from Amnesic Populations

Some of the most persuasive evidence favouring distinct implicit and explicit systems of memory comes from studies of amnesic patients. While these participants perform poorly on tests of explicit memory, due to the nature of brain lesions linked to amnesia, some have argued that their ability on tests of implicit memory is equivalent to that of control participants. Early studies stumbled upon this finding when amnesic patients were able to show normal word recall in relation to controls when they were given the initial letters of the word as a cue (Mayes, Meudell, & Neary, 1978; Mortensen, 1980;

Squire, Wetzel, & Slater, 1978; Warrington & Weiskrantz, 1970; 1974). A later experiment by Graf, Squire, and Mandler (1984) showed that cued recall in amnesic patients was indistinguishable from control participants when the instructions of the task were changed to promote the use of implicit retrieval strategies (e.g., report the first word that comes to mind) rather than explicit ones (recall words studied previously in the task). Since these early studies, research has extended these results to encompass a variety of implicit tasks such as repetition priming (Bowers & Schacter, 1993; Graf & Schacter, 1985; Hamann & Squire, 1997; Schacter & Graf, 1986; Tulving & Schacter, 1990; Cermak, Talbot, Chandler, & Wolbarst, 1985; Haist, Musen, & Squire, 1991) and artificial grammar learning (Knowlton, Ramus, & Squire, 1992; Knowlton & Squire, 1994; 1996). These dissociations are of considerable value to proponents of distinct implicit and explicit memory systems, because they appear to provide evidence for the existence of a type of memory that operates independently from conscious processing.

Conversely, there have been instances when amnesic patients do not show explicit memory impairments (Huppert & Piercy, 1976; 1978), or spared implicit memory (Chun & Phelps, 1999; Squire, Shimamura, & Graf, 1987). Ostergaard and Jernigan (1993) attribute these mixed results to the low reliability and power of most implicit memory measures to detect underlying between-groups differences, and propose that researchers should not present null between-groups effects as unambiguous proof that implicit processing is spared in amnesic populations. Ostergaard (1999) even questioned whether the original results from early word-stem completion studies (Milner, 1968; Warrington & Weiskrantz, 1968; Weiskrantz & Warrington, 1970) support the idea that priming is spared in amnesia, since improved retention performance with the induction of word fragment cues in amnesic participants was usually still significantly lower than the control group in these early studies.

Other research has drawn attention to the validity of obtained dissociations as evidence of a memory distinction. Demonstrations of some ability to learn on an implicit test occurring in the presence of poor performance on an explicit test can be based on a single memory trace, i.e., mediated by a unitary memory system (Kinder & Shanks, 2001; 2003; Nosofsky, & Zaki, 1998; Speekenbrink, Channon, & Shanks, 2008). Using a generalized context model that adjusted a memory sensitivity parameter based on the amnesic patients' inherently impaired storage of exemplars, Nosofsky and Zaki (1998) reproduced the dissociation shown by Knowlton and Squire (1993) of implicit categorization of visual dot patterns without subsequent awareness on a recognition task using a single storage exemplar process to support performance on both the categorization and recognition tasks in their model.

Kinder and Shanks (2001) successfully simulated the results obtained by Knowlton et al. (1992), which showed intact implicit classification without explicit recognition in an artificial grammar learning task in an amnesic population, using a single process recurrent network (SRN) model that assumed a reduced learning rate in the amnesic population. The SRN model was also able to reproduce results from Knowlton and Squire (1996) showing poor recognition in amnesic patients for chunks of grammar sequences and intact classification ability in relation to control participants. Moreover, in Kinder and Shanks (2001) the SRN model was also extended to predict intact repetition priming without significant recognition ability shown in studies of amnesic patients (Hamann & Squire, 1997a; 1997b). The results of that simulation implicated inherent differences between priming and recognition tasks as the source of these performance dissociations rather than distinct memory processes. Similarly, in their final study Kinder and Shanks demonstrated that impaired priming accompanied by intact recognition in a patient with lesions to the occipital lobe in Gabrieli, Fleischman, Keane, Reminger, and Morrell (1995) was not a consequence of an implicit memory impairment, but instead was mediated by a visual processing deficit.

A further study by Speekenbrink et al. (2008) applied a dynamic lens model to results from amnesic patients on a weather prediction task, which is a probabilistic category learning task requiring participants to use a rule to predict outcomes based on a set of cues and then assign probabilistic weights to each cue as a means of explicitly reporting task knowledge. This study found that learning shown via prediction performance was equivalent between amnesic and control participants, and more importantly showed that prediction performance and later task knowledge were related. Neither of these results is predicted by a multiple-systems model of memory.

The success of these simulations using single system models contradicts the idea of a selective explicit memory impairment in amnesic patients, and suggests that a general memory deficit is present that affects both explicit and implicit memory.

1.2.3 Evidence from Older Populations

Demonstrations of age invariant performance on an implicit memory task are often viewed as evidence in favour of distinct implicit and explicit mechanisms of learning and memory. The logic of these types of behavioural dissociations is that implicit memory proceeds normally in older populations because only cognitive functioning mediated by conscious processing is susceptible to age-related deterioration.

Although there is a vast amount of the literature suggesting that healthy older adults do not perform any differently from younger adults on tasks supported by implicit memory (Knopman & Nissen, 1987; Light & Albertson, 1989; McGeorge et al., 1997), there is at the same time a considerable body of evidence showing implicit memory impairments in older adults (Abbenhuis, Raaijmakers, Raaijmakers, & van Woerden, 1990; Cherry & Stadler, 1995; Chiarello & Hoyer, 1988; Howard, 1988; La Voie & Light, 1994; Light & Singh, 1987).

Salthouse et al. (1999) proposed that results statistically different from chance in older and younger participants reported in many papers may be indicative of the inherent lack of reliability in typical implicit task measures, rather than evidence that implicit abilities remain intact with advanced age. That is to say, even if a finding of equivalent implicit performance has been empirically established, the measures that make up the phenomenon may still reflect inconsistent data on the individual level. Moreover, a lack of an effect could be an artefact of low reliability rather than an indication of behavioural equivalence. By testing a large group of participants (n = 183) ranging in age from 18 to 87 years old using an extensive range of standardized measures of explicit memory, processing speed, and implicit memory, Salthouse et al. (1999) found data to suggest that certain implicit memory tests (i.e., artificial grammar or associative learning tasks) are not reliable enough for investigating individual differences. The only implicit task with the appropriate level of reliability to detect age-related differences in performance, according to Salthouse et al. (1999), is the SRT task.

Early studies using the SRT task found that older adults were capable of showing sequence learning (Knopman & Nissen, 1987; Nissen & Bullemer, 1987); however, these studies did not employ tests of awareness so Howard and Howard (1989, 1992) re-examined sequence learning in an older population with direct comparison to a younger population and using varying lengths of sequences. Both studies found no difference in implicit sequence learning by age. Sequence length also negatively affected learning to the same extent in each age group, but the older adults were markedly worse than younger adults on the awareness test in the longer 16- and 20-element sequences, which asked participants to predict elements of the sequence at certain intervals.

In contrast, other examinations of the SRT task in ageing populations have found evidence of age-related deficits in performance (Cherry & Stadler, 1995; Curran, 1997; Curran, Smith, DiFranco, & Daggy, 2001; Feeney, Howard, & Howard, 2002; Howard & Howard, 1997; Howard & Howard, 2001; Howard et al. 2004; Jackson & Jackson, 1992) when the sequences employed higher-order predictive relationships. Curran (1997) reasoned that older adults' sequence learning deficits may become more evident when sequences possess more complex relationships, grounding this explanation in recurrent-network models of sequence learning (Cleeremans & McClelland, 1991; Keele & Jennings, 1992). Because working memory capacity diminishes with age, it may be more difficult for larger chunks of sequence knowledge to retain predictive value. Other explanations of deficits also tend to explain age-related sequence learning impairments in terms of the general memory decrements older people have been shown to experience (Cherry & Stadler, 1995; Feeney et al, 2002; Howard et al., 2004).

The majority of criticisms of implicit memory research in older populations argue that a general memory impairment is the mechanism of age-related deficits in these sorts of tasks, which also lends support for the perspective that memory should not be defined on the basis of consciousness at processing (Reder et al. 2009).

1.3 The Spatial Contextual Cuing Paradigm

Chun and colleagues reported results from studies using a *spatial contextual cuing paradigm* (Chun & Jiang, 1998). Whereas most implicit learning and memory tasks are concerned with adaptations in the way in which words or objects are processed, contextual cuing relates to the no less important issue of scene learning. When we enter a familiar room we do not search randomly for our coffee cup – predictive contextual cues guide our search and attention to the most probable locations (e.g., the table). In contextual cuing, participants learn associative relationships between repeating spatial layouts of distracter letters and the location of a target stimulus in displays viewed during visual search. Participants are shown displays containing a set of 12 letter stimuli and are required to detect a target stimulus (a letter T) within the subset of distracter stimuli (11 letter L's). Crucially, the location of the target in half of the displays appears repeatedly with the same arrangement of the distracters surrounding it. This learning is expressed through the gradual development of search efficiency for these repeated displays, indicating that repetitive exposure to these distracter configurations results in the acquisition of a mental representation that becomes relied upon to guide search.

Contextual cuing is claimed to engage purely implicit processing because when given a direct test of explicit knowledge – such as having to generate the location of a missing target during a generation test (Bennett, Romano, Howard, & Howard, 2008; Bennett, Barnes, Howard, & Howard, 2009; Chun & Jiang, 2003; Park et al., 2004) or making a recognition judgment (Barnes et al. 2008; Chun & Jiang, 1998; 1999; Chun &

Phelps, 1999; Howard et al., 2004; Huang, 2006; Howard, Howard, Japikse, & Eden, 2006; Manns & Squire, 2001; Nabeta, Ono, Kauahara, 2003; Pollman & Manginelli, 2009; Schankin & Schubo, 2009; van Asselen et al., 2009) – participants perform no better than they would through random guessing (but see Brockmole & Henderson, 2006; Endo & Takeda, 2005; Ono, Kauahara, & Jiang, 2005; Olson & Jiang, 2004; Olson et al. 2005; Ono et al., 2005; Peterson, Kramer, & Colcombe, 2002; Preston & Gabrieli, 2008; Vaidya, Huger, Howard, & Howard, 2007).

Further evidence that contextual cuing operates on an unconscious level was demonstrated by Jiang and Leung (2005), who manipulated attention during learning. Participants viewed displays with stimuli in 2 colours and were instructed to attend to a certain colour of distracter stimuli and ignore the other colour throughout learning. A contextual cuing effect emerged even for the unattended-colour distracters, which suggests that contextual cuing is not contingent upon conscious attention to the relevant stimuli.

The findings described above support the notion that contextual cuing employs strictly implicit processing that is fundamentally distinct from explicit memory. However, Chun and Phelps (1999) found that amnesics with hippocampal and medial temporal lobe damage show impaired contextual cuing, and concluded that this was a demonstration that these memory structures were crucial to performance in the task. Similar results were obtained by Ryan, Althoff, Whitlow, and Cohen (2000), who showed that an amnesic population was unable to exploit cues when performing an analogous visual search task with real-word images, leading these authors to conclude that amnesic patients possess a binding deficit which may prevent formation of cue-layout associations in these types of implicit tasks (but see Smith, Hopkins, & Squire, 2006). Park et al. (2004) also examined contextual cuing in amnesia; however, this study utilized the drug midazolam to create cases of “synthetic” anterograde amnesia in a group of control participants. This drug is known to induce explicit memory impairments in normal healthy individuals, while leaving implicit task performance unaffected (Arndt, Passannante, & Hirshman, 2004; Curran, DeBuse, Woroch, & Hirshman, 2006; Thomas-Anterion, Koenig, Navez, & Laurent, 1999). The synthetic amnesic participants in Park et al. (2004) did not demonstrate contextual cuing, akin to findings in actual amnesic patients in Chun and Phelps (1999), while the control group of participants, who received a dose of saline, showed contextual cuing but no ability to recognize learned patterns on an awareness test. Collectively, these studies converge on the idea that brain structures that are causally linked with the explicit memory impairments experienced by amnesic patients, such as the hippocampus, may also be involved in contextual cuing.

Recent neuroimageing data from Greene, Gross, Elsinger, and Rao (2007) confirmed that the hippocampus was involved with contextual cuing, even when recognition did not exceed chance (but see Preston & Gabrieli, 2008). Greene et al. (2007) argued that activation of the hippocampus during performance signals that the processing involved with encoding the complex associative relationships entailed in contextual cuing can only proceed intentionally. Such a result also implies that a behavioural dissociation between learning and awareness for a given piece of information may not necessarily reflect its possession of a unique implicit property, but instead may indicate that this information is represented at a lower level of quality or strength which makes it unable to support performance on an explicit test (Shanks, 2005).

1.3.1 Age Invariant Contextual Cuing

In a series of experiments, Howard et al. (2004) examined sequential learning and contextual cuing in a single group of healthy older participants, who exhibited typical explicit memory impairments in relation to a group of younger control participants on standardized measures of recall and working memory. The older adults failed to show evidence of learning on a SRT task, yet their performance on a contextual cuing task showed no difference from younger adults. Younger participants were able to wilfully generate sequential information in the SRT task, demonstrating conscious awareness for the knowledge learned, while subsequent contextual cuing ability was not accompanied by the ability to recognize learned displays on a direct test of knowledge. Finding impaired SRT performance in the presence of intact contextual cuing ability in older people was not only taken as proof that explicit memory does not support contextual cuing, but also that purely implicit processing is not affected by cognitive ageing.

The criticisms of implicit tasks put forth by Salthouse et al. (1999) also apply to these experiments. Reaction times, as shown in older populations, are known to be highly variable (Chapman, Chapman, Curran, & Miller, 1994), which could make it difficult for an ANOVA to detect underlying performance differences. In fact, a graph of response times from both groups in Howard et al.'s Experiment 1 across the contextual cuing task shows that learning may have occurred in younger participants before older participants. A difference in learning onset would imply that older adults might not have picked up on the contextual information contained in repeated displays as quickly as younger adults did. However, since Howard et al. (2004) did not include more detailed comparisons of task performance, there are no means of determining when learning first occurred for each participant group or if the magnitude of the contextual cuing effect by the end of the task was equivalent.

The role of awareness in the analysis of these experiments also provokes some concern. The direct test used in Howard et al. (2004) measured participants' ability to discriminate repeated displays shown throughout the visual search portion of the task from completely novel displays (Chun & Jiang, 1998), which is neither the most powerful nor the most sensitive test of awareness. Discrimination judgments are often supported by familiarity or perceptual fluency (Jacoby, Kelley, Dywan, 1989; Whittlesea, Jacoby, Girard, 1990), and in addition the recognition process in this sort of task does not engage the same processes entailed by the visual search task where contextual cuing knowledge is encoded (Shanks & St. John, 1994). Performance on such a test may not actually evoke the same memory trace used to support a contextual cuing effect during the visual search task; therefore, a null effect in recognition may not mean that contextual cuing knowledge is not consciously retrievable. Chun and Jiang (2003) proposed a revised direct test, which showed participants the repeated displays from the search task, but this time the target letter they were supposed to search for was substituted with a distracter letter. Participants were then asked to generate the location of the missing target letter, forcing them to localize the target based on the spatial configuration of distracter letters in the display and providing a closer match to the initial process that supported encoding of contextual cuing knowledge. Given that Chun and Jiang (2003) rectified these methodological problems via the generation test, it is unclear why Howard et al. (2004) decided to include a recognition test as a means of gauging awareness.

Another relevant problem to consider in tests of explicit knowledge, as considered in greater detail previously, is their statistical power (Buchner & Wippich, 2000). While the visual search task contains many hundreds of trials to assess contextual cuing, the direct tests traditionally included in contextual cuing experiments are made up of only 24 trials to probe for conscious awareness. This disparity in the number of data points contributing to each measure provokes some concern. We would expect lengthening an awareness test to substantially increase the power of the explicit measure. It is therefore unclear whether Howard et al. (2004) would have still obtained dissociable contextual cuing and recognition performance if the explicit measure had included more trials.

The ideas described above offer some alternate interpretations of contextual cuing in older adults, as well of the dissociations between learning and awareness in younger adults found in Howard et al. (2004). This thesis aims to reconcile these issues by asking whether older adults are able to show intact learning in this task, examining whether the factors that contribute to contextual cuing are similar across older and younger adults, and questioning if contextual cuing can occur independently from conscious awareness.

2 Contextual Cuing in Older Adults

The experiment reported in this chapter looked at cognitive ageing in the setting of implicit memory using a contextual cuing task (Chun & Jiang, 1998). The contextual cuing learning effect is a relatively stable finding in younger adults (Chun & Jiang, 1998; Chun & Jiang, 2003; Preston & Gabrieli, 2008; Smyth & Shanks, 2008); however, it is unclear how performance is affected by the general age-related cognitive decrements that occur in healthy older adults. As described in Chapter 1, contextual cuing was first examined in an ageing population by Howard et al. (2004). Howard et al.'s (2004) main finding was that older participants showed marked impairments in relation to younger controls on an SRT task, but the same older individuals performed at a comparable level to a younger control group on a contextual cuing task. These findings led Howard et al. (2004) to conclude that the SRT and contextual cuing tasks rely upon distinct neurological structures that are differentially affected by cognitive ageing.

The conclusion that age-constant learning occurred in the contextual cuing task was based on rather weak evidence (i.e., a null result). Previous experiments in contextual cuing have reported reliable learning in younger participants after as few as 12 blocks of trials in the detection task (Chun & Jiang, 1998; 1999). A similar learning effect was apparent for younger adults in Experiment 1 of Howard et al. (2004); however, a graph plotting each age group's RT data in each epoch of the task clearly showed that older adults developed contextual cuing much later, after about 20 blocks of trials. Nevertheless, because the ANOVA failed to show a three-way interaction with age, Howard et al. concluded that the amount of response facilitation for repeating displays across the task was equivalent in older and younger participants. An alternative interpretation is that this null effect was due to insufficient power in the ANOVA to detect the older group's apparent underlying contextual cuing deficit. The older adults as a group also showed efficient responding to the repeated configurations when their data were analysed separately, an indication that learning of these displays' contextual layouts occurred. In fact, the only indication of an age difference in performance, statistically, was the slower overall response speed of older adults, which Howard et al. (2004) conjectured might have masked their performance deficits.

In light of this, it is difficult to evaluate Howard et al.'s (2004) conclusion that contextual cuing is age invariant. Instead, it seems important to re-examine the effects of cognitive ageing in the contextual cuing paradigm to address the concern described above. In Experiment 1, we examined the delayed emergence of contextual cuing in older in relation to younger participants implied by the trend in Howard et al.'s (2004) data by altering the length of the learning phase in the contextual cuing task.

2.1 Experiment 1

If older participants require more repetitions of the contextual cues before showing learning, this deficit should become more apparent after a shorter task duration, prior to an asymptotic level of learning being reached. In Experiment 1, we examined this possibility by shortening the 30 block (6 epochs) detection task used by Howard et al. (2004) to include only 16 blocks (4 epochs) of trials. Fewer blocks of trials should still produce reliable contextual cuing in younger participants, but if older participants learn at a slower rate than younger participants, as suggested by Howard et al.'s data, they should show little sign of an effect with less exposure to the task.

2.1.1 Method

2.1.1.1 Participants

Twenty older adults ranging from 55 to 88 years old (*M* = 69.20, *SD* = 10.08) and 20 younger adults ranging from 19 to 30 years old (*M* = 23.40, *SD* = 3.14) volunteered to participate in this study, and were paid a baseline incentive of £3 plus an additional 10 pence for every configuration identified correctly in the recognition task. Older participants were recruited from a local senior community centre and the University College London (UCL) participant database, while all younger participants were recruited from the UCL participant database. The participant groups were matched for gender and education (Table 2.1). The older participants scored lower than younger participants on several sub-scales of the Wechsler Memory Scale (WMS-III) (3rd ed., Wechsler, 1997b), all t's > 2.11, p's < .05, confirming performance decrements known to manifest themselves with age.

***Table 2.1.* Participant Demographics in Experiment 1**

	Younger (n = 20)	**Older** (n = 20)
Gender		
Female	13	13
Male	7	7
Age	M = 23.40 (3.14)	M = 69.20* (10.08)
Education (years)	M = 14.40 (1.27)	M = 13.55 (2.39)
Memory		
WMS-III Logical Memory I Recall	M = 40.55 (13.19)	M = 28.60* (11.10)
WMS-III Logical Memory II Recall	M = 26.65 (9.58)	M = 15.10* (8.14)
WMS-III Logical Memory Recognition	M = 25.30 (2.70)	M = 22.10* (6.23)
WMS-III Logical Memory Retention	M = 81.9 (16.70)	M = 59.50* (18.72)

Numbers in brackets denote standard deviations.
* $p < .001$

2.1.1.2 Design

The detection task was a 2 x 2 x 4 mixed-factorial design (Age Group x Repetition x Epoch) with Age Group (Older and Younger) as a between-subjects variable, and Repetition (Repeated and Non-Repeated configurations) and Epoch (1-4) manipulated within-subjects. Each participant's RT for detecting the target letter in the configuration of distracters was measured on each search trial. A post-learning recognition task employed a 2 x 2 x 2 (Age Group x Repetition x Block) mixed-factorial design. Response accuracy in discriminating configurations seen during the detection task from completely novel configurations was measured in each block.

2.1.1.3 Materials and Apparatus

The detection and recognition tasks were modified versions of the contextual cuing task described in Chun and Jiang (1998), and were programmed using Visual Basic software to generate all stimuli and measure participant responses. On each trial, the participant viewed a configuration of 11 letter-L distracters and 1 rotated letter-T target against a grey background, and identified the orientation of the target letter (either left or right) in the display as quickly as possible. A set of 12 Repeated configurations of letters were presented in each block, while the remaining 12 trials in the block contained new configurations that were shown only once during the task (Non-Repeated configurations). A unique set of 12 Repeated and 192 Non-Repeated configurations were generated for each participant, and the order of presentation of Repeated and Non-Repeated configurations was randomised in each block.

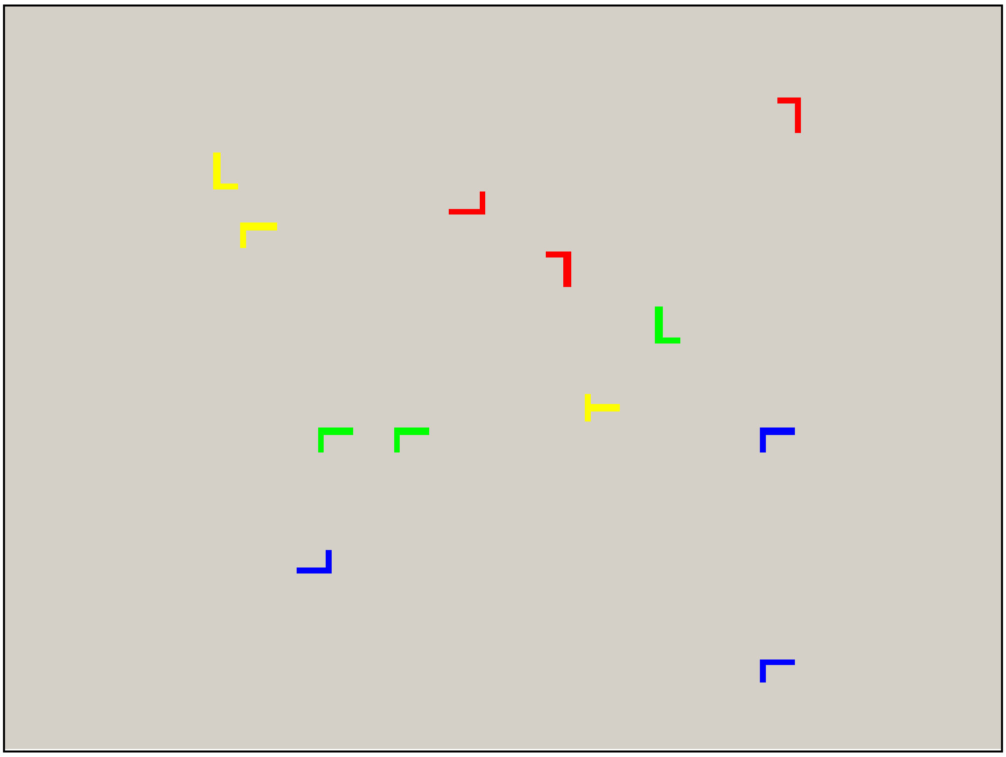


Figure 2.1. **An example display of letters seen by participants during the detection and recognition tasks.**

All letter stimuli appeared in 30 pt. Arial font at a visual angle of 0.76° at a viewing distance of approximately 60 cm. The 21cm x 21cm screen was divided into an 8 x 8 grid of possible locations, then subdivided into a 4 quadrant invisible matrix. Three letters coloured red, green, yellow, or blue were then randomly assigned to a spatial location in each quadrant, which resulted in each configuration containing 3 letters in each colour. The spatial locations of the target letter Ts were evenly distributed across the 4 quadrants of the screen within each block and configuration condition to control for location probability effects. The locations of the target letter T in the Non-Repeated configurations shown in each block were always chosen from the same set of 12 counterbalanced spatial locations generated at the beginning of the task. Each T was rotated 90° to the right or left, and each

L was shown at 0°, 90°, 180°, or 270°. The location and colour of all letters in each Repeated configuration were kept constant with each presentation, with the exception of the varying and unpredictable orientation of the letter T: the location, but not the orientation, of the T was predictable from the distracter configuration on Repeated trials.

In the recognition task, participants were shown 2 blocks of 24 trials. The format of each block was identical to the detection task: 12 Repeated configurations and 12 Non-Repeated configurations shown in a random sequence. The Repeated configurations were carried over from the detection task, while a new set of 24 Non-Repeated configurations was generated for the recognition task using the same stimulus criteria used in the detection task. Participants were asked to discriminate between Repeated configurations they had seen previously and novel Non-repeated configurations as a means of assessing awareness.

2.1.1.4 Procedure

The experiment began with administration of the Logical Memory sub-scale of the WMS-III. Next, participants were given instructions regarding the detection task. The instructions provided onscreen examples of configuration stimuli and the 2 possible orientations of the T, and asked participants to locate the letter T within the configuration of Ls then respond by indicating the direction it is pointing using the left and right arrows on the keyboard. Participants were advised to respond quickly and accurately, but they were not informed that they should pay attention to any of the configurations for patterns or repetitions. The main experiment began after 6 practice trials to establish task familiarity. The presentation of each configuration was preceded by an orienting white dot (1 cm x 1 cm) for 1 sec in the centre of the screen. Each configuration was displayed until a response was made, then auditory feedback was provided to the participant according to the accuracy of the response. A high-pitched tone (1800 hz) lasting 200 ms signified a correct answer, and a longer 800 ms, low-pitched tone (200 hz) signified an incorrect answer. Each individual trial was separated by a further 700 ms inter-trial-interval The blocks of detection trials were separated by a break of at least 10 sec., after which participants could either continue resting if necessary, or press the space bar to progress to the next block.

After the detection task, participants were asked to answer questions designed to assess their awareness for the repeated configurations. Specifically, all participants were asked, "During the experiment, do you think that any of the particular configurations of Ls repeated?" Those who were aware of the repetition then received 2 further follow-up questions. The first asked, "Approximately, when did you being to notice this repetition?", then participants were required to estimate the point in the task in which awareness occurred using a slider labelled by block from 1 to 16. The final question asked "After you realised particular configurations of Ls were being repeated, did you try to memorise these displays?"

After completing the awareness questionnaire, all participants received instructions for the recognition task. Participants were informed of the repetition of certain configurations throughout the detection task, and told the recognition task would gauge their knowledge of these repeated configurations. The instructions explained to participants that they would see 24 repeated configurations randomly intermixed with 24 newly generated configurations, and asked them to indicate their responses using the letter 'O' on the keyboard on trials containing a configuration shown earlier in the detection task (Old configurations), or the letter 'N' on trials displaying a configuration they did not recognise from the detection task (New configurations).

Participants were told that RT was not measured in this portion of the experiment, and advised to concentrate and respond as accurately as possible since they would also receive 10 pence for every correctly identified configuration. No auditory feedback was given in the recognition task, and a new trial was only initialised after a response to the current trial had been made. After completing the recognition task, participants were given on-screen feedback of their recognition performance, then administered the remaining portion of the WMS-III. Although the duration of the detection and recognition tasks varied across individuals, the interval between administrations of the WMS-III was kept constant at 60 min for all participants.

2.1.2 Results

2.1.2.1 Detection Task

An ANOVA with Repetition as a within-subjects variable (Repeated versus Non-Repeated) and Age (Older or Younger) as a between-subjects variable was used to analyse mean accuracy in responding to the direction of the target letter in the detection task. There was no main effect of Age, $F(1, 38) = 1.18$, $p > .28$, signifying that all participants in the detection task demonstrated high accuracy overall (Older, M = 99%, SE = 0.21; Younger, M = 99%, SE = 0.29). There was also no main effect of Repetition or Repetition x Age interaction, F's < 2.24, p's > .14, which indicates that responses made while viewing Non-Repeated configurations were just as accurate Repeated configurations overall in the experiment and within each age group (Older, Repeated, M = 99%, SE = 0.30; Non-Repeated, M = 99%, SE = 0.30; Younger, Repeated, M = 99%, SE = 0.30; Non-Repeated, M = 99%, SE = 0.30).

The median RTs for correct responses were calculated for each set of Repeated and Non-Repeated configurations in each block, then averaged across blocks to yield a Repeated and Non-Repeated RT for each 4-block epoch (shown in Figure 2.2). A repeated-measures ANOVA with Repetition (Repeated versus Non-Repeated) and Epoch (1-4) as within-subjects variables and Age (Older or Younger) as a between-subjects variable showed a main effect of Age on RT, $F(1, 38) = 17.81$, $p < .001$, reflecting the Older group's slower responding overall in the task compared to the Younger group (Older, $M = 2030$ ms, $SE = 177$; Younger, $M = 1249$ ms, $SE = 54$). There is a motor learning component to the task that caused participant to make more efficient responses with task practice, as indicated by a significant main effect of Epoch (Epoch 1, $M = 1777$ ms, $SE = 116$; Epoch 4, $M = 1582$ ms, $SE = 113$), $F(3, 114) = 14.52$, $p < .001$.

More interestingly, there was also a Repetition x Epoch x Age interaction, $F(3, 114) = 3.41$, $p = .02$, indicating that greater response efficiency developed across the task (Epoch 1 minus Epoch 4) for Repeated configurations in relation to Non-Repeated configurations (i.e., contextual cuing) in Younger participants (Repeated, $M = 276$ ms, $SE = 45$; Non-Repeated, $M = 149$ ms, $SE = 37$), compared to Older ones (Repeated, $M = 165$ ms, $SE = 77$; Non-Repeated, $M = 192$ ms, $SE = 93$). No other interactions approached significance, all F's < 1.71, all p's > .26.

A follow-up ANOVA of RTs in just the last epoch revealed a significant Repetition x Age interaction confirming that contextual cuing differed between Older and Younger participants (Older, Repeated, $M = 2010$ ms, $SE = 195$; Non-Repeated, $M = 1982$ ms, $SE = 167$; Younger, Repeated, $M = 1107$ ms, $SE = 56$; Non-Repeated, $M = 1229$ ms, *SE* = 56), $F(1, 38) = 3.97$, $p = .05$. There was no main effect of Repetition, $F(1, 38) = 1.54$, $p > .22$.

An individual analysis of Younger participants' data across the task confirmed that contextual cuing occurred in this group, as revealed by both a main effect of Repetition, $F(1, 19) = 4.43$, $p < .05$, and a Repetition x Epoch interaction, $F(3, 57) = 9.76$, $p < .001$. Critically, the same analysis of the Older group's data showed neither a main effect of Repetition, $F(1, 19) = 0.74$, $p > .40$, nor a Repetition x Epoch interaction, $F(3, 57) = 1.04$, $p > .38$. Individual *t*-tests on each epoch substantiated these differences in performance, since a contextual cuing effect was apparent in Younger participants by Epochs 3 and 4 of the task, t's > 2.54, p's < .02, whereas Older participants showed no sign of a difference in RTs between configurations at any point, all t's < 1.70, p's > .10.

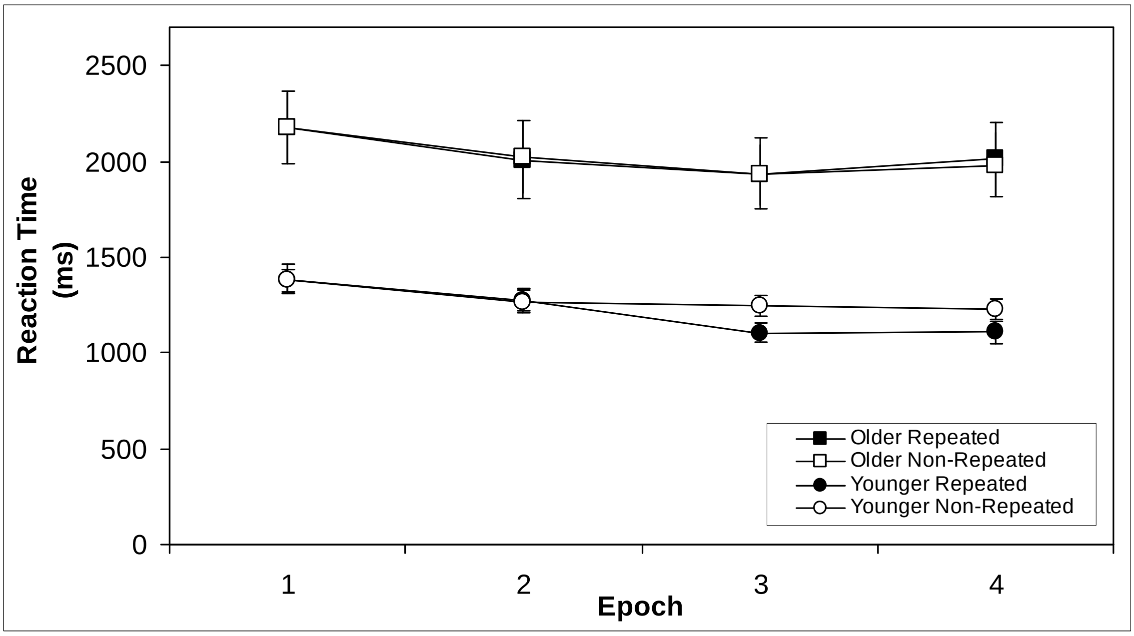


Figure 2.2. **Means of the median reaction times (ms) for Older and Younger participants over 4 epochs (epoch = 4 blocks) of the detection task in Experiment 1; error bars represent standard errors.**

One way of taking the overall difference in response speed between age groups into account is to calculate a proportional measure of learning by dividing the difference between Non-Repeated and Repeated RTs in the last epoch by the Non-Repeated RT [(Non-Repeated-Repeated)/Non-Repeated]. Greater contextual cuing is signified by high positive proportional contextual cuing scores. Figure 2.3 plots these proportional scores for the 2 groups, and shows that when baseline response speed is factored out, Older participants still showed lower levels of contextual cuing compared to Younger participants, $t(38) = 2.45$, $p < 0.02$. In fact, the Older group's contextual cuing was not statistically different from zero, $t(19) = 0.36$, $p > .72$.

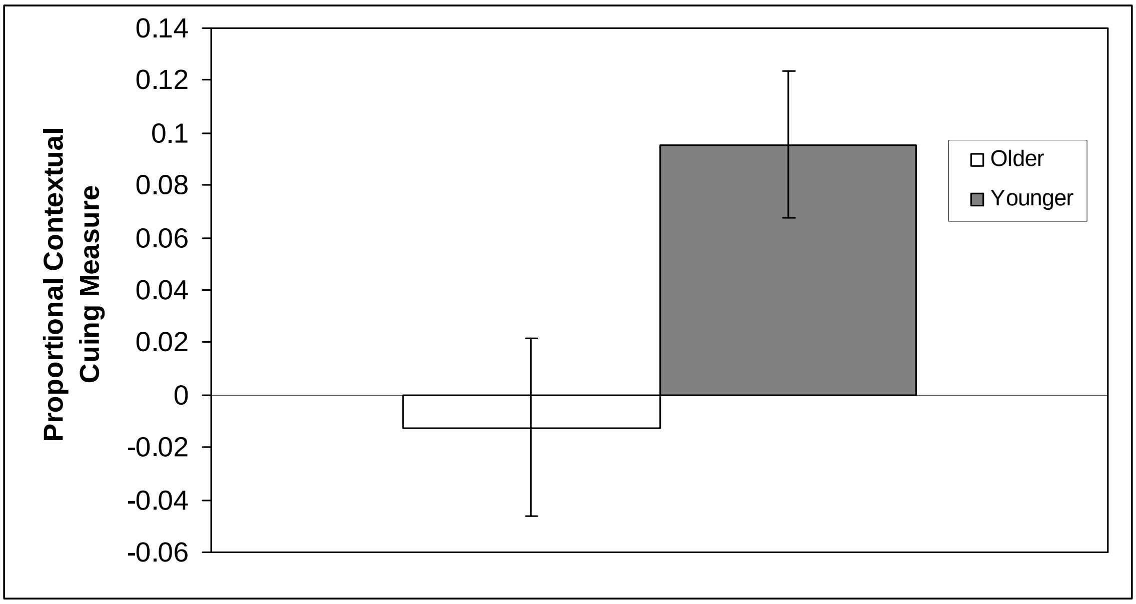


Figure 2.3. **Mean proportional measure of contextual cuing in Experiment 1. This is calculated by dividing the difference between Non-Repeated and Repeated RTs in the last epoch of the task by the Non-Repeated RT [Non-Repeated-Repeated/Non-Repeated]; error bars represent standard error.**

2.1.2.2 Recognition Task

Conscious memory for Repeated configurations was assessed by comparing participants' ability to correctly discriminate these configurations from novel ones. Figure 2.4 plots hits (an 'Old' response to a Repeated display) versus false alarms (an 'Old' response to a Non-Repeated display), which were compared using a repeated-measures ANOVA with Trial Type [Old (Repeated) vs. New (Non-Repeated)] and Block (1-2) included as within-subjects variables and Age (Older or Younger) as a between-subjects variable. This analysis showed a main effect of Trial Type, $F(1, 38) = 6.17$, $p < .02$, (Hits, $M = 0.55$, $SD = 0.13$; False alarms, $M = 0.48$, $SD = 0.12$), meaning that participants were able to discriminate between old and new displays. There was a marginal main effect of

Age, $F(1, 38) = 3.32$, $p = .08$, and a marginal Age x Trial Type x Block interaction, $F(1, 38) = 3.82$, $p = .06$, suggesting a difference in recognition ability between age groups, although the Age x Trial Type interaction, $F(1, 38) < 1$, did not approach significance.

More importantly, in separate analyses of recognition performance, a main effect of Trial Type, $F(1, 19) = 8.39$, $p < .01$, revealed evidence of awareness in the Younger group while the Older group showed no such effect, $F(1, 19) = 1.02$, $p > .32$. The fact that Younger participants showed neither a main effect of Block, $F(1, 19) = 0.42$, $p > .52$, nor a Trial Type x Block interaction, $F(1, 19) = 2.54$, $p > .12$, suggests that significant awareness was stable across the recognition task.

Both awareness and contextual cuing were present in the Younger group, while neither of these effects were detected in the Older group. This suggests that conscious memory ability may be linked to contextual cuing. In order to explore this possibility, we correlated performance on the Logical Memory sub-scales of the WMS-III (Table 2.1) and the proportional cuing score in each age group. The majority of these correlations were weak and non-significant, Older, r's < 0.11, p's $> .49$; Younger, r's < -0.10; p's $> .68$. There was a moderate negative relationship between performance on the Retention scale in the WMS-III and the proportional cuing score shown in the Younger group, $r = -0.30$, though this correlation also failed to achieve significance, $p > .20$.

2.1.2.3 Reported Awareness Results

Fourteen Older participants (70%) and 16 Younger participants (80%), $\chi^2 = 0.53$, $p > .46$, reported noticing the repetition of configurations, with awareness occurring on average at block 5 of the task for both groups, $t(38) = 0.29$, $p > .77$. Two (14%) Older and 3 (19%) Younger aware individuals used a memorization strategy after the repetition became apparent. However, it is unlikely that realizing certain displays were repeating facilitated detection performance in this experiment, since ANOVAs of performance in each age group did not yield any significant interactions with reported awareness (Aware or Unaware) when it was included as an additional between-subjects variable, all F's < 1.91, all p's > .13. Further individual analyses of performance sub-divided by awareness were also consistent with the overall results, in that both Aware and Unaware Younger participants still showed Repetition x Epoch interactions, F's > 4.69, p's < .03, while neither a main effect of Repetition nor a Repetition x Epoch interaction was obtained in Aware or Unaware Older participants, all F's < 1.42, p's > .28.

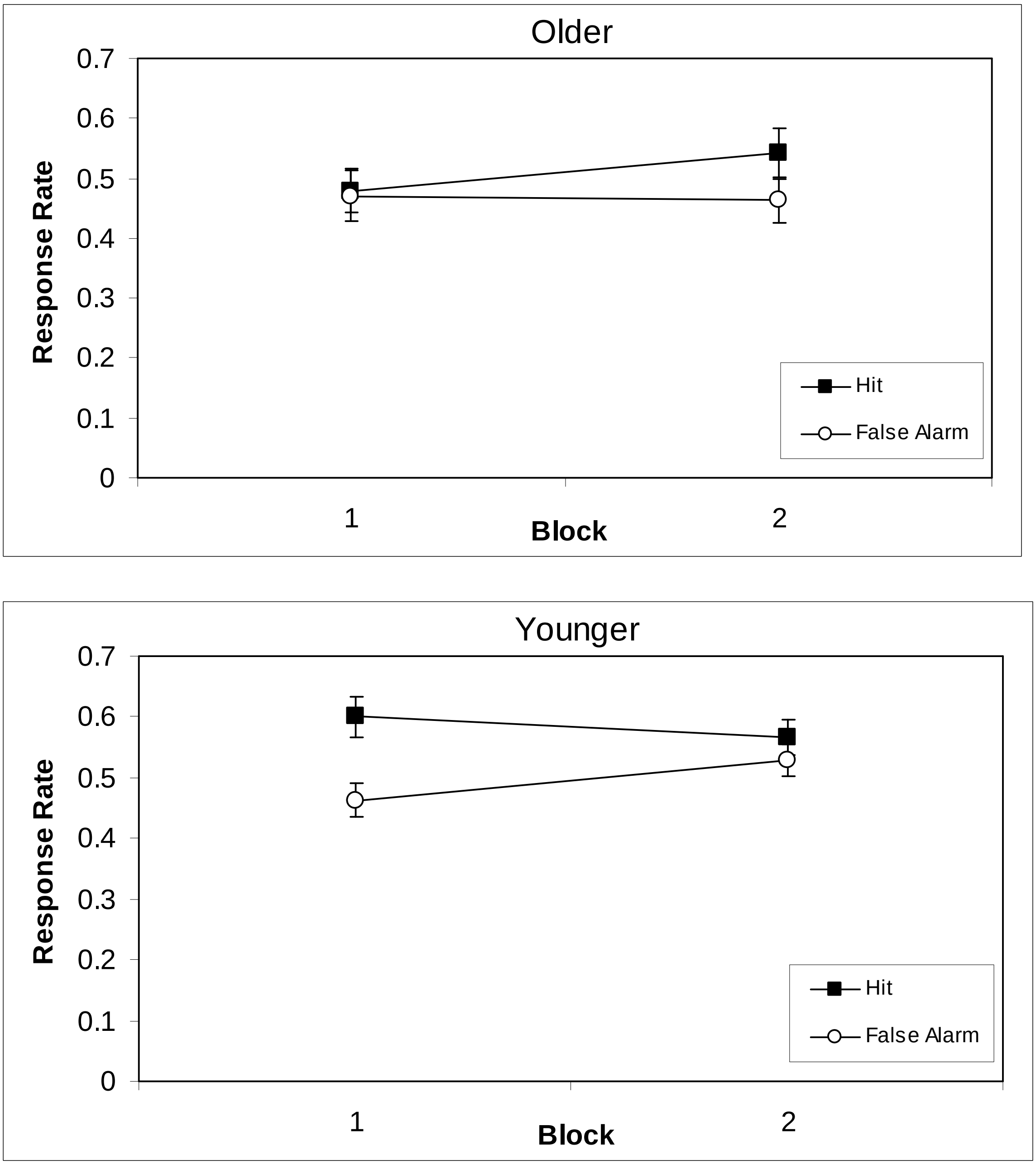


Figure 2.4. **Recognition performance for Older and Younger participants in Experiment 1; error bars represent standard errors.**

2.1.3 Discussion

This experiment was concerned with examining whether the longer task duration employed in Experiment 1 of Howard et al. (2004) masked differences in the onset of learning indicative of contextual cuing impairments in older adults. When a shorter task was used here, the results showed that younger adults still developed gradual search efficiency as well as the ability to later recognize Repeated configurations during an awareness test, yet older adults showed no evidence of learning or awareness. Younger adults displayed a reliable contextual cuing effect after only 12 exposures (3 epochs) to these contextual cues, whereas older adults still failed to show contextual cuing after 16 exposures (4 epochs). While Howard et al. (2004) concluded that older and younger adults performed at equivalent levels in the contextual cuing task, the findings from this experiment indicate that the lack of age group differences reported in that study may have been a by-product of insensitive statistical measures and near-asymptote learning. Instead, it seems that older adults require more exposure to repeating contextual configurations than younger adults before displaying evidence of learning.

Previous research has proposed that contextual cuing relies exclusively on implicit processing; therefore, participants showing more efficient visual search during the detection task should not show subsequent conscious access to this information in a test of awareness (e.g., recognition or generation). Here, contextual cuing was clearly accompanied by explicit recognition in the Younger group. We will return to the consideration of single and dual-systems models of memory as pertaining to contextual cuing in Chapter 4; however, the presence of awareness using a block-design version of the test employed in this experiment questions the purity of the implicit processing entailed in the contextual cuing task.

In addition to showing a lack of awareness and a later onset of learning, older people also exhibited much slower responding in the detection task compared to younger ones. Some studies have proposed that learning measures based on RT are artificially inflated in older participants with slower baseline speed, because higher RTs allow for more potential to develop response efficiency (Howard et al, 2004; Howard, Howard, Dennis, & Yankovich, 2007, Fleischman, 2007; Manns & Squire, 2001). Experiment 2 of Howard et al. (2004) specifically examined the possibility that older adults' slower responding obscured an age-related contextual cuing deficit by looking at performance in younger participants using a more difficult detection task to inflate RTs; however, when this slower younger group's performance was compared to the older group in their Experiment 1 there were no indications of performance differences.

It is relatively well-established that ageing is accompanied by slower response times on a variety of speeded tasks (Light, 1991; Park & Reuter-Lorenz, 2009; Salthouse, 1980), which has prompted many to conclude that performance on these tasks is adversely affected by the deterioration of neural processing with age. Achard and Bullmore (2007) showed that ageing resulted in less efficient transmission of signals between and within the orbitofrontal, lateral temporal, and medial temporal regions in older individuals, when they compared functional connectivity between the cortical and subcortical regions in the brains of younger and older adults during a resting state.

In Processing Speed theory (Salthouse, 1985; 1996), the slower baseline speed of responding systematically shown by older participants on cognitive tasks is assumed to be indicative of general slowing. Cognitive slowing diminishes processing efficiency, hindering the ability to preserve information waiting to be processed in the periphery while performing fundamental cognitive operations. Consequently, these mechanisms produce degraded or incomplete representations of relevant information that are crucial to task performance, which results in lower levels of memory performance in slow older populations. A large body of evidence can be marshalled showing that age-related cognitive decline is often eliminated when general processing speed is included as a covariate. Contextual cuing impairments in amnesics and children have also been accompanied by slower overall RTs in comparison to controls (Howard et al., 2004; Vaidya, Huger, Howard, & Howard, 2007).

This raises the question of whether slower processing speed prevented older adults in Experiment 1 from encoding as much information about the contextual associations in Repeated configurations. In the next chapter, a cognitive slowing explanation of older adults' contextual cuing deficits is explored in a group of younger participants by altering properties of the displays to simulate the slower responses of older adults.

3 Processing Speed and Contextual Cuing

The study described in Chapter 2 demonstrates that older adults have difficulty exploiting the spatial cues contained in the contextual cuing task to the same degree as younger adults, therefore questioning Howard et al.'s (2004) claim of age constancy in contextual cuing. Although it is possible that the older group's impairments in Experiment 1 indicate that a task-specific processing decline occurs with age, the fact that such impairments were also accompanied by slower overall response latencies leads us to consider cognitive slowing as another plausible explanation of the older group's performance.

In the series of experiments presented in this chapter, cognitive slowing is addressed as a possible mechanism for the older adults' contextual cuing deficits in Experiment 1. In Experiments 2 and 3, with younger participants, the display properties were altered to increase search difficulty and to simulate the slower response latencies of older people. Experiment 4 examined the converse hypothesis, whether older adults' contextual cuing ability improved when they received a less difficult search task to make their response latencies faster.

3.1 Experiment 2

The approach that is adopted in this experiment investigates the influence of cognitive slowing on contextual cuing performance in a group of healthy younger adults when their response speeds are similar to those of older adults. Using younger participants eliminates the confounding influence of memory deficits known to develop with age, but it can be difficult to find a method to sufficiently simulate the cognitive slowing that causes longer response latencies in older adults. Supporters of the notion that age-related slowing is the underlying cause of cognitive decline do not normally sanction simply using slowed stimulus pacing or allowing unlimited time to respond as a method of eliminating performance differences between older and younger adults (Park, 1992). Merely slowing down younger adults is not enough. The manipulation should produce slower responding by impeding the encoding of contextual information contained in repeated configurations. In other words, it needs to simulate the mechanisms that cause a processing lag in cognitive ageing.

Chun and Phelps (1999) successfully slowed down younger participants to match the response times of amnesic participants by increasing the difficulty of visual search in the detection task, specifically using altered distracter letter Ls that looked more similar to the target letter T. Howard et al. (2007), using an SRT task, found that lowering the contrast ratio between the stimuli and the display background also increased younger participants' response times and led to degraded sequence learning. The present experiment imposes both of these manipulations on groups of younger participants to determine whether cognitive slowing can sufficiently account for the contextual cuing impairments demonstrated by older adults in Experiment 1. Reduced levels of contextual cuing in these artificially slower younger participants would implicate slower response speed as the cause of older adults' contextual cuing impairments.

3.1.1 Method

3.1.1.1 Participants

One-hundred and twenty undergraduate students took part in this experiment (89 women and 31 men), and received credit for part of an introductory Psychology course at University College London. All of the participants were between 18 and 30 years old (*M* = 19.77, *SD* = 2.61). The visual appearance of the displays shown in the experiment differed between participants. Forty participants performed the task seeing a low contrast difference between the letter stimuli and background screen, another group of 40 participants saw distracter letters with an offset manipulation, and finally there were 40 participants in a control condition who received a standard version of the task, similar to that used in Experiment 1, that did not contain any display manipulations (all shown in Figure 3.1).

3.1.1.2 Design

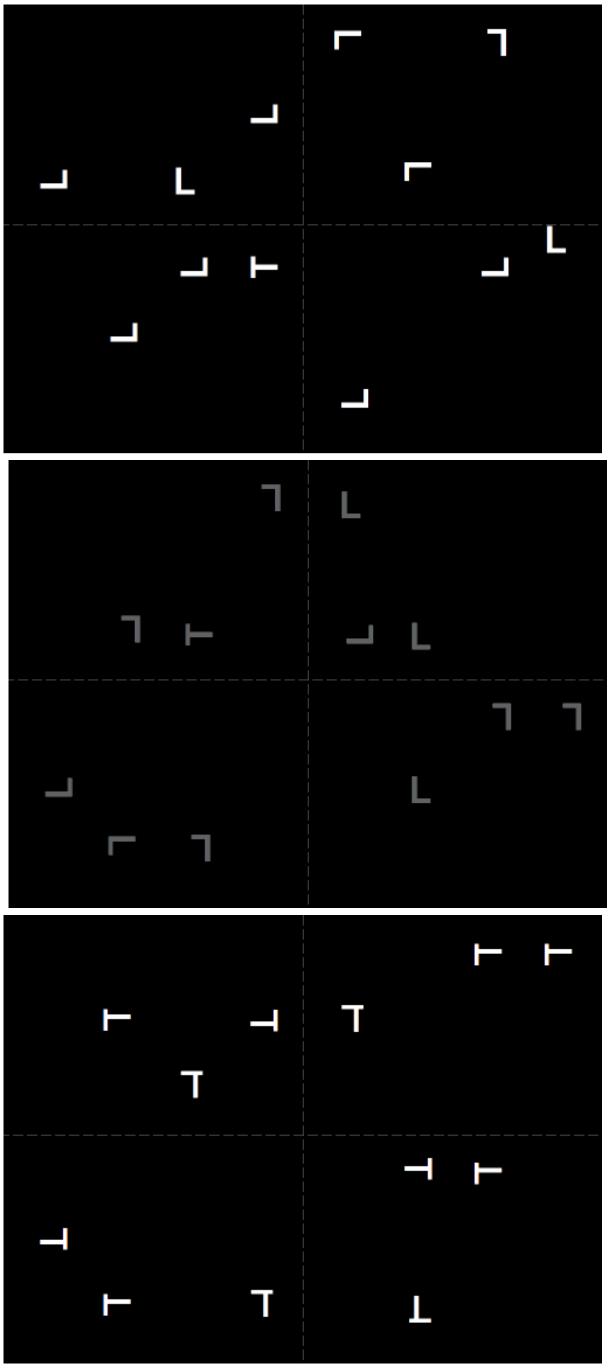
Participants only performed the detection task, which was a 3 x 2 x 4 mixed-factorial design (Display Condition x Repetition x Epoch) with Display Condition (Offset, Contrast, or Control) as a between-subjects variable, and Repetition (Repeated and Non-Repeated) and Epoch (1-4) manipulated within-subjects. The detection task measured RT for detecting the target letter and accuracy in identifying the orientation of the target in the configuration for each trial. The recognition awareness test was not included in this experiment, because the focus was on how learning varied with overall response speed. Participants still received the series of awareness questions from Experiment 1 after the detection task.

3.1.1.3 Materials and Apparatus

The instructions and procedure described in Experiment 1 were slightly modified for creating and presenting all of the configurations of letters used for this experiment. The colour manipulation included in the original experiments by Chun and colleagues was removed so that all stimuli were presented in white against a grey background. The detection task in the Control group was identical to that used in Experiment 1, but the display properties viewed by participants in the Offset and Contrast groups were altered in order to slow down response times. In the Offset group, the vertical segment of each distracter letter L was offset by 0.34 cm from the horizontal line of the letter, which made it more difficult to detect the target amongst the distracters. In the Contrast group, the screen colour contrast between the grey background and the letters in the display was reduced from maximum contrast to a 38% contrast level, making it difficult to distinguish the entire display of letters (target and distracters) from the screen background.

3.1.1.4 Procedure

Participants received instructions asking them to search for the letter T in the display of letter Ls as quickly and accurately as possible. Each set of instructions included a visual example of the type of display seen throughout the task, which was customized for each participant group. Participants were also informed that they were prohibited from adjusting any of the display settings manually. All other aspects of the detection task were identical to Experiment 1.



(a)
(b)
(c)

Figure 3.1. **The displays shown in each Display Condition of the detection task: (a) Control, (b) Contrast, and (c) Offset. The grey background colour of these displays during the experiment has been changed to black to emphasise the contrast manipulation.**

3.1.2 Results

3.1.2.1 Detection Task

The display manipulations produced different response accuracies between viewing conditions. An ANOVA with Repetition as a within-subjects variable (Repeated versus Non-Repeated) and Display Condition (Control, Contrast, or Offset) as a between-subjects variable, revealed a main effect of Viewing Condition, $F(2, 117) = 13.71$, $p < .001$. Participants in the Control and Contrast groups demonstrated high accuracy overall (Control, $M = 98\%$, $SE = 0.17$; Contrast, $M = 99\%$, $SE = 0.15$), $t(78) = 1.71$, $p > .09$, while participants in the Offset group found it more difficult to distinguish targets from distracters leading to significantly lower response accuracy than the Control and Contrast groups ($M = 97\%$, $SE = 0.38$), t's > 3.43, p's < .001. Nevertheless, there were no differences in response accuracy for Repeated and Non-Repeated configurations overall, $F(2, 117) = 2.83$, $p > .10$, or in any of the Display Conditions, $F(2, 117) = 0.78$, $p > .46$.

A repeated-measures ANOVA was used to compare detection latencies between the groups (shown in Figure 3.2), and included Repetition (Repeated and Non-Repeated) and Epoch (1-4) as within-subjects variables and Display Condition (Control, Contrast, or Offset) as a between-subjects variable. There was a main effect of Display Condition, $F(2, 117) = 268.19$, $p < .001$, confirming that the display manipulations produced considerable differences in response speed between groups with more than a doubling of response times in the Offset group (Control, $M = 1053$ ms, $SE = 44$; Contrast, $M = 1268$ ms, $SE = 29$; Offset, $M = 2986$ ms, $SE = 99$). Recall that the purpose of these manipulations was to artificially match younger participants' response speed to older participants, so we compared the speeds of Offset and Contrast participants to the Older adults in Experiment 1. It was expected that Offset participants would be slower in relation to Control participants, $t(78) = 17.88$, $p < .001$; however, somewhat surprisingly they were also slower than the Older group in Experiment 1 ($M = 2030$ ms, $SE = 177$), $t(58) = 5.11$, $p < .001$. The Contrast participants, although slower than the Control group, $t(78) = 4.07$, $p < .001$, responded faster than Older participants in Experiment 1, $t(58) = 5.81$, $p < .001$.

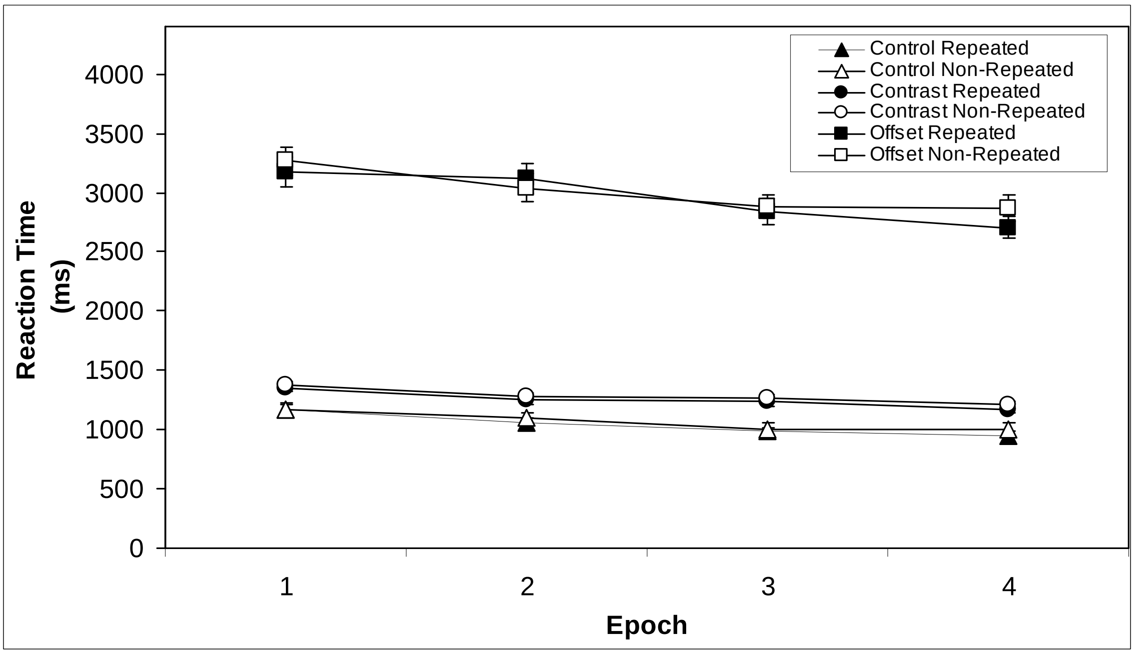


Figure 3.2. **Means of the median reaction times (ms) for younger Control, Contrast, and Offset groups in Experiment 2; error bars represent standard error of the mean.**

All participants responded faster with practice, as shown by an overall main effect of Epoch, $F(3, 321) = 48.73$, $p < .001$, but there was also an Epoch x Display Condition interaction, $F(6, 351) = 5.95$, $p <.001$, suggesting that the amount of speed up from Epoch 1 to Epoch 4 differed between Display Conditions (Control, $M = 142$ ms, $SE = 23$; Contrast, *M* = 175 ms, *SE* = 20; Offset, *M* = 436 ms, *SE* = 69). This difference is probably a consequence of the Offset group's slower responding allowing more opportunity to develop motor efficiency.

Although the Repetition x Display Condition interaction did not approach significance, $F(2, 117) < 1$, and the main effect of Repetition, $F(1, 117) = 3.68$, $p = .06$, and the Repetition x Epoch interaction, $F(6, 321) = 2.52$, $p = .06$, were only marginally significant, the presence of a reliable three-way Repetition x Epoch x Display Condition interaction, $F(6, 351) = 2.13$, $p < .05$, suggested that contextual cuing developed at different rates across groups.

An ANOVA of Repeated and Non-Repeated configuration RTs during the last epoch showed an overall main effect of Repetition, $F(1, 117) = 14.27$, $p < .001$, indicative of a difference in RTs by the end of the task, and revealed only a marginal Repetition x Display Condition interaction, $F(2, 117) = 2.61$, $p > .08$, which is most likely due to greater learning produced by the offset manipulation. Further pairwise comparisons of RT data in the last epoch also showed that a significant detection advantage resulted for Repeated configurations in all 3 Display Conditions (Control, *M* = 57 ms, *SE* = 18; Contrast, *M* = 42 ms, *SE* = 25; Offset, *M* = 159 ms, *SE* = 61), all *t*'s > 1.71, all *p*'s < .05 (1-tailed). Indeed, in absolute terms, the group most similar to the older group from Experiment 1 in terms of baseline RT – the Offset group – showed the largest learning effect.

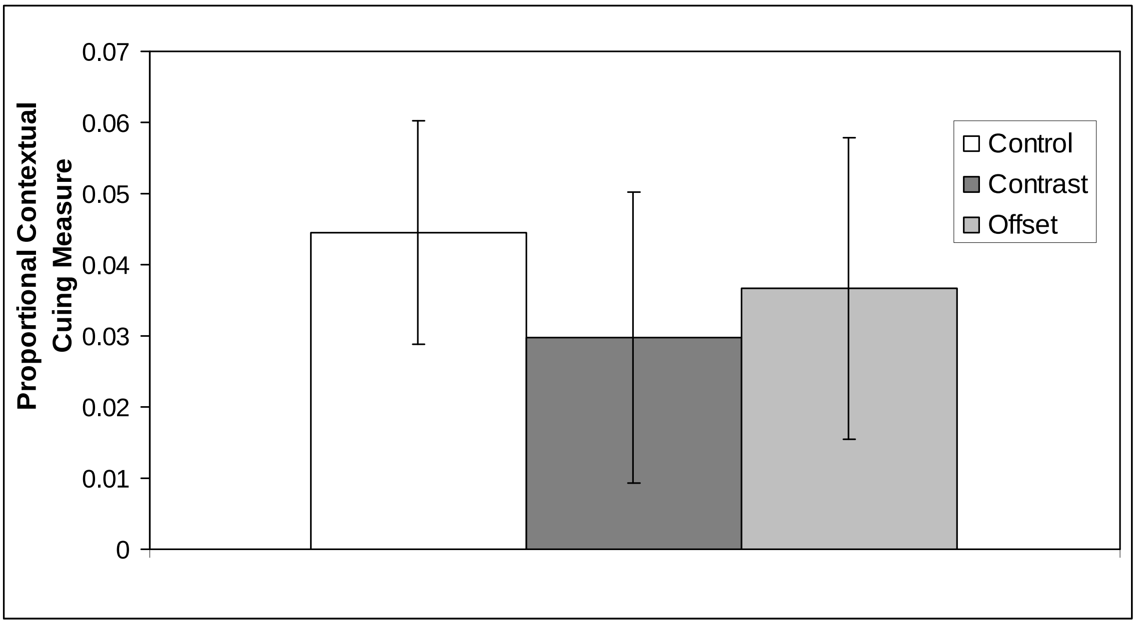


Figure 3.3. **Mean proportional measure of contextual cuing across younger participant groups in Experiment 2; error bars represent standard error.**

As discussed in Experiment 1, there is a danger that learning can be overestimated when measured by RT differences, since there is more scope for developing efficiency when RTs start out high. Therefore, a proportional contextual cuing score was again calculated to quantify learning while taking into account baseline response speed within each group as in Experiment 1 (Figure 3.3). Consistent with the difference scores, there was no difference in cuing levels between groups, $F(2, 117) < 1$, indicating that contextual cuing did not diminish in younger participants when their processing speed was artificially slowed down to match the speed of older adults in Experiment 1. However, only the Control and Offset groups' contextual cuing scores were statistically greater than zero, t's > 1.73, $p < .05$ (one-tailed).

3.1.2.2 Reported Awareness Results

Sixty-four percent (77/120) of participants reported detecting the repetition manipulation and a further 10% of these individuals engaged in a memorisation strategy after they noticed that repetitions occurred. There were marginal statistical differences across groups in the number of participants who reported awareness (Control = 70%; Contrast = 73%; Offset = 50%), $\chi^2 = 5.29$, $p > .07$, and no differences in the number of aware participants who tried to memorise Repeated configurations (Control = 11%; Contrast = 10%; Offset = 10%), $\chi^2 = 0.27$, $p > .87$. A repeated-measures ANOVA of the detection data including reported awareness as a between-subjects variable showed neither a main effect of nor any significant interactions with Awareness, all *F*'s < 1.66, *p*'s > .20. This leads us to conclude that performance was not affected by an underlying realization that displays may have repeated during the detection task.

3.1.3 Discussion

This experiment aimed to address concerns raised by the slower response times that accompanied the contextual cuing impairments demonstrated by older adults in Experiment 1, which suggest that poor performance may be a corollary of slower processing speed associated with cognitive ageing. In this experiment, we were able to simulate the perceptual-motor slowing of the older adults in Experiment 1 in younger adults by altering the properties of the displays. These display manipulations slowed down response times to different degrees, with the offset adjustment inducing the greatest degree of slowing.

Despite the severity of their processing speed impairment, Offset participants still showed equal levels of contextual cuing to the Contrast and Control participants in this experiment. In fact, the only consequence of slowing was an increase in the Offset participants' capacity to develop motor efficiency with practice, which has typically been shown in past studies that have employed similar offset manipulations (Chun & Phelps, 1999; Manns & Squire, 2001). Ideally the offset manipulation would have produced similar response impediments across younger participants, indicating that a similar level of cognitive slowing had been applied. The overall response time of the Offset group across the task indicates that the altered letter stimuli provoked slower responding on a group level; however, applying a uniform amount of offset to the distracter stimuli slowed down participants to varying degrees (as evident by high variability in the Offset group's overall response latency).

3.2 Experiment 3

Experiment 2 compared contextual cuing in younger participants when the properties of the display were modified to produce slower responses. Altering the contrast of the display did not slow down detection performance enough to afford comparison to the speed of responding of older adults in Experiment 1. Yet while the offset manipulation significantly impeded participants' detection speed on the whole, contextual cuing was not impaired. Experiment 3 attempts to replicate this result using a more tailored offset manipulation intended to control for the surprising amount of individual differences shown in the Offset group in the previous experiment. In this experiment, the computer program titrates the amount of offset applied to the distracter letters according to younger participant's response speed at predefined intervals to calibrate response speed to the latencies shown by older participants.

Recall that in Experiment 1 we found that younger adults showed a substantial contextual cuing effect by the end of a 16 block detection task, whereas older adults did not show evidence of learning at all, and Howard et al. (2004) found that a contextual cuing effect in older and younger adults developed after a 30 block detection task. This led us to believe that the reason we did not find contextual cuing in older adults may have been because Experiment 1 used a shorter detection task. Consequently, the duration of the detection task in Experiment 3 was lengthened to match the procedure of Howard et al. (2004) and an older control group was included in this study.

3.2.1 Method

3.2.1.1 Participants

Thirty older adults ranging in age from 59 to 83 years old (M = 67.65, SD = 7.47) and 30 younger adults between 18 and 30 years old (M = 23.07, SD = 3.47) volunteered to take part in the study. Older participants were recruited via an advertisement in a local newspaper, while all younger participants came from the UCL Psychology subject pool. All participants were in good health and free from diagnoses of neurological disorders, and were paid £15 for their time plus an additional 10 pence for every configuration identified correctly in the generation task. These groups were matched for gender, education, and on the vocabulary subscale from the Wechsler Adult Intelligence Scale (WAIS-III) (3^{rd} ed., Weschler, 1997a), but as expected (shown in Table 3.1), differed in performance on several tests of memory and processing speed taken from the Weschler Memory Scale (WMS-III) (3^{rd} ed., Weschler, 1997b) and the WAIS-III, all t's > 2.03, all p's < .05.

Table 3.1. ***Participant Demographics in Experiment 3***

	Slow Younger (n = 30)	**Older** (n = 30)
Gender		
Female	19	20
Male	11	10
Age	M = 23.07 (3.47)	M = 67.65* (7.47)
Education (years)	M = 14.87 (1.50)	M = 14.63 (2.27)
Memory		
WMS-III Logical Memory I Recall	M = 46.03 (7.68)	M = 34.70* (9.83)
WMS-III Logical Memory II Recall	M = 29.30 (6.01)	M = 21.33* (6.62)
WMS-III Logical Memory Recognition	M = 27.03 (2.28)	M = 25.40* (2.49)
WMS-III Logical Memory Retention	M = 87.58 (9.55)	M = 85.11 (17.45)
Adult Intelligence Scale		
Vocabulary	M = 48.17 (6.34)	M = 47.87 (13.46)
Digit Span	M = 19.83 (3.99)	M = 17.97* (3.06)
Digit Symbol Coding Task	M = 96.80 (19.06)	M =61.60* (14.93)

Numbers in brackets denote standard deviations.
* $p < .05$

3.2.1.2 Design

The design of the detection task was a 2 x 2 x 7 mixed-factorial (Age Group x Repetition x Epoch), with Age Group (Older or Slow Younger) as a between-subjects variable, and Repetition (Repeated and Non-Repeated) and Epoch (1-7) manipulated within-subjects. The generation task was a 2 x 2 x 4 (Age Group x Repetition x Block) mixed-factorial design, with Age Group (Older or Slow Younger) as a between-subjects variable, and Repetition (Repeated and Non-Repeated) and Block (1-4) manipulated within-subjects. Each participant's accuracy in responding to the location of the missing target letter in each trial was measured for each configuration condition in each block during the generation task.

3.2.1.3 Materials and Apparatus

The instructions and procedure described in Experiment 1 were slightly modified for creating and presenting all of the configurations of letters used for this experiment. The colour manipulation included in the original experiments by Chun and colleagues was also removed so that all stimuli were presented in white against a grey background, and the length of the detection task from Experiment 1 was extended from 16 to 30 blocks of trials (from 4 to 7 epochs). These task modifications were performed in order to replicate the procedure used in Howard et al. (2004).

The display properties were also altered to slow down the response time of Younger participants. Specifically, the vertical segment of each distracter letter L was offset from the horizontal line of the letter. The amount of offset applied to the distracter letters varied between individual participants from 1.16 mm to 2.17 mm and depended on the participants' speed of responding during Block 1 of the task. The program calibrated the offset for each participant by taking the mean RT at 3 different intervals in the first block (after trials 8, 16, and 24), then increasing the amount of offset applied to the letter Ls if the speed of responding was faster than the criterion RT of 3,550 ms (the baseline response speed of older adults in the control condition). At the end of the first block of trials, the amount of offset applied remained constant for the remainder of the task. The amount of offset applied was increased by 0.34 mm for half of the participants to make the target letters more difficult to discern from distracter letters, because the smaller offset of 0.24 mm did not consistently slow down responses in Slow Younger participants. The Older group did not receive this initial calibration manipulation in Block 1, but they were presented with slightly offset distracter stimuli (1 mm) on all trials to minimise any general perceptual processing differences caused by the offset manipulation.

Awareness was measured using a generation task, replacing the recognition task, because past research has shown that generation is more sensitive in gauging awareness than recognition (Chun & Jiang, 2003). For this reason, each display in the detection task now appeared with 2 grey dotted lines bisecting the screen horizontally and vertically, which divided the screen into 4 equal quadrants to aid later in the generation task.

The generation task was made up of 4 blocks of 24 trials each. The format of a single block was identical to a block in the detection task: 12 Repeated configurations and 12 Non-Repeated configurations shown in a random sequence in each block. The Repeated configurations were carried over from the detection task, while a new set of 48 Non-Repeated configurations was created specifically for the generation task. However, all of the configurations shown in the generation task differed from the detection task stimuli in that all T's in the detection configurations were replaced with L's.

3.2.1.4 Procedure

The experiment began with the administration of the Logical Memory I scale of the WMS-III. The remainder of the memory tests shown in Table 3.1 were given upon completion of the detection and generation tasks (approximately 60 minutes later). The detection task progressed exactly as in Experiment 1, starting with instructions to participants to locate the T in the configuration using the arrow keys followed by on-screen examples of a configuration and the new offset letter stimuli. After the 6 practice trials, the Older participants proceeded with the detection task exactly as in Experiment 1, while Slow Younger participants received a calibration block of 24 trials so that the right amount of offset could be applied in the remaining 29 blocks of trials to adequately slow down their responses. At the end of the detection task, participants answered the same series of awareness questions administered in the previous two experiments.

Immediately afterward, participants performed the generation task. The instructions informed all participants that they had in fact been presented with a repeated series of configurations during the detection task, and explained that the generation task would test their knowledge of these repeated configurations. The task requirements were presented as a slight variation of the detection task, in that participants were told that they would see a set of configurations similar to those seen previously, but this time the T would be replaced with an L. The instructions for the generation task prompted participants to respond with the quadrant location of this substitute L using the numeric keypad on the right-hand side of the keyboard. The response layout on the keypad mimicked the spatial layout of the quadrants in the display, with the “7” and “9” keys corresponding to the top left and right quadrants and the “1” and “3” keys corresponding to the bottom left and right quadrants. It was emphasized that responding as accurately as possible was a priority in this phase of the experiment, and that it was more important to concentrate on the correct answer, not the time taken to respond. A new configuration was presented only after a valid response was given, and without an orienting dot or breaks between blocks of trials. At the end of the task, participants were informed of their accuracy, then the experimenter administered the remaining subscales of the WAIS. The duration of the experiment was roughly 2 hours.

3.2.2 Results

3.2.2.1 Detection Task

Slow Younger group showed lower accuracy in identifying the orientation of the target stimulus than the Older group (Slow Younger, M = 91%, SE = 1.38; Older, M = 99%, SE = 0.11), which was confirmed by the presence of a main effect of Age Group in the ANOVA of response accuracy during the detection task, $F(1,58) = 32.07$, $p < .001$. This was expected since the offset manipulation made it difficult to identify the target letter among similar-looking distracter stimuli. Response accuracy was similar for Repeated and Non-Repeated configurations during the detection task overall and within each group (Slow Younger, Repeated, M = 92%, SE = 1.41; Non-Repeated, M = 91%, SE = 1.41; Older, Repeated, M = 99%, SE = 0.15; Non-Repeated, M = 99%, SE = 0.11), as made evident by the fact that neither the main effect of Repetition, nor the Repetition x Age Group interaction approached significance, F's < 1.28, p's > .26.

RTs from the first block of trials were excluded from all analyses, because this served as a calibration block for the Slow Younger group. The median RTs for each configuration type in each block (shown in Figure 3.4) were calculated using only correct responses from Blocks 3-30. Data from Block 2 were also excluded from the analyses so that a uniform number of blocks (4) could be collapsed into each epoch. The average RT for Non-Repeated configurations in the first epoch was used to measure the speed of responding, and showed that the offset manipulation was successful in matching response latency between participant groups (Slow Younger, $M = 3872 \pm 207$ ms; Older, $M = 3523 \pm 155$ ms), $t(58) = 1.37$, $p > .18$.

Although half of participants in the Slow Younger group received more perceptually similar stimuli (with 0.34 cm offset increments applied to the distracter letters rather than 0.24 cm increments), there were no statistical differences in response speed, $t(28) = 1.44$, $p > .16$, or detection performance, all F's < 1.78, all p's > .19, when these sub-groups were compared.

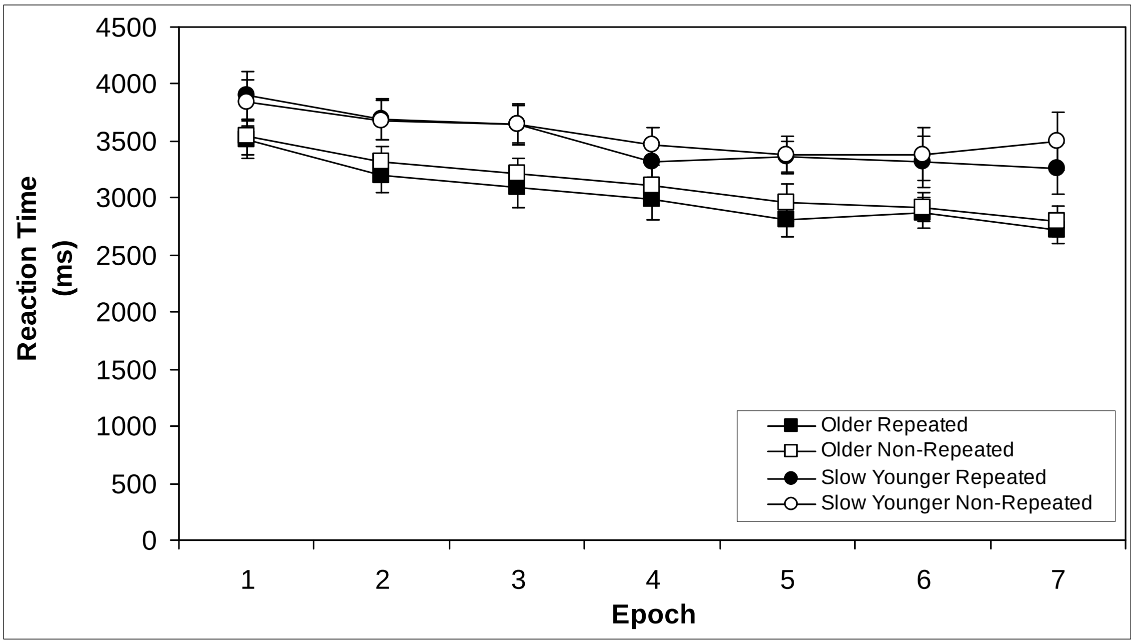


Figure 3.4. **Means of the median reaction times (ms) for Older participants and Slow Younger participants, in a detection task of 7 epochs (Blocks 1 and 2 omitted; each epoch = 4 blocks); error bars represent standard error of the mean.**

A repeated-measures ANOVA was used to analyse detection performance, and included Repetition (Repeated and Non-Repeated) and Epoch (1-7) as within-subjects variables and Age (Older or Slow Younger) as a between-subjects variable. Participants responded faster in general with task practice, as shown by a main effect of Epoch,

$F(6, 348) = 15.74$, $p < .001$. More importantly, there was also a main effect of Repetition, $F(1, 58) = 4.25$, $p < .05$, suggesting that overall participants responded more efficiently to Repeated configurations. However, the non-significant Repetition x Epoch interaction, $F(6, 348) < 1$, suggests that this difference may have occurred quite early on in the detection task.

The ANOVA also showed an overall main effect of Age, $F(1, 58) = 4.75$, $p < .04$, which indicates that RTs in the Slow Younger group exceeded those in the Older group. Although there were no significant interactions with Age, all F's < 1, as discussed in Chapter 2, null effects should be interpreted with caution as there may have been insufficient statistical power to detect more subtle performance differences. Consequently, the Slow Younger and Older data sets were analysed using separate ANOVAs.

Findings from an ANOVA of RTs in the Older group were consistent with the overall ANOVA, in that there was a significant main effect of Epoch, $F(6, 174) = 29.72$, $p < .001$, and no Repetition x Epoch interaction, $F(6, 174) < 1$. The main effect of Repetition approached significance, $F(1, 29) = 3.78$, $p = .06$, so follow-up pairwise comparisons between Repeated and Non-Repeated RTs in each epoch were performed to see if a detection advantage for Repeated configurations was present at any point in the task. These comparisons indicated that Older participants did not develop a response speed advantage for Repeated configurations over Non-repeated configurations, all t's < 1.67, all p's > .10.

An individual ANOVA of performance in the Slow Younger group also continued to show a main effect of Epoch, $F(6, 174) = 3.79$, $p < .001$; however, neither the main of effect of Repetition, $F(1, 29) = 1.02$, $p > .32$, nor the Repetition x Epoch interaction,

$F(6, 174) = 1.16$, $p > .33$, approached significance. These findings imply that the stimulus manipulations imposed in this version of the detection task prevented contextual cuing from occurring in the Slow Younger group.

A proportional measure of contextual cuing was also computed in this task, using the method employed in the previous experiments (Figure 3.5). Older and Slow Younger individuals showed statistically equivalent levels of learning, $t(58) = 1.02$, $p > .31$, but the Slow Younger group’s proportional cuing score was statistically different from zero, $t(29) = 2.08$, $p < .05$, while the Older group’s was not, $t(29) = 0.56$, $p > .58$. This subtle difference may imply that the Slow Younger group showed some evidence of contextual cuing in the task, but the group’s higher response times may have obscured an underlying cuing effect from achieving significance in the ANOVA. Alternatively, as discussed in the Discussion section of Chapter 2, it is also possible that their artificially inflated response times also gave Slow Younger participants a greater propensity to develop a response advantage for Repeated configurations.

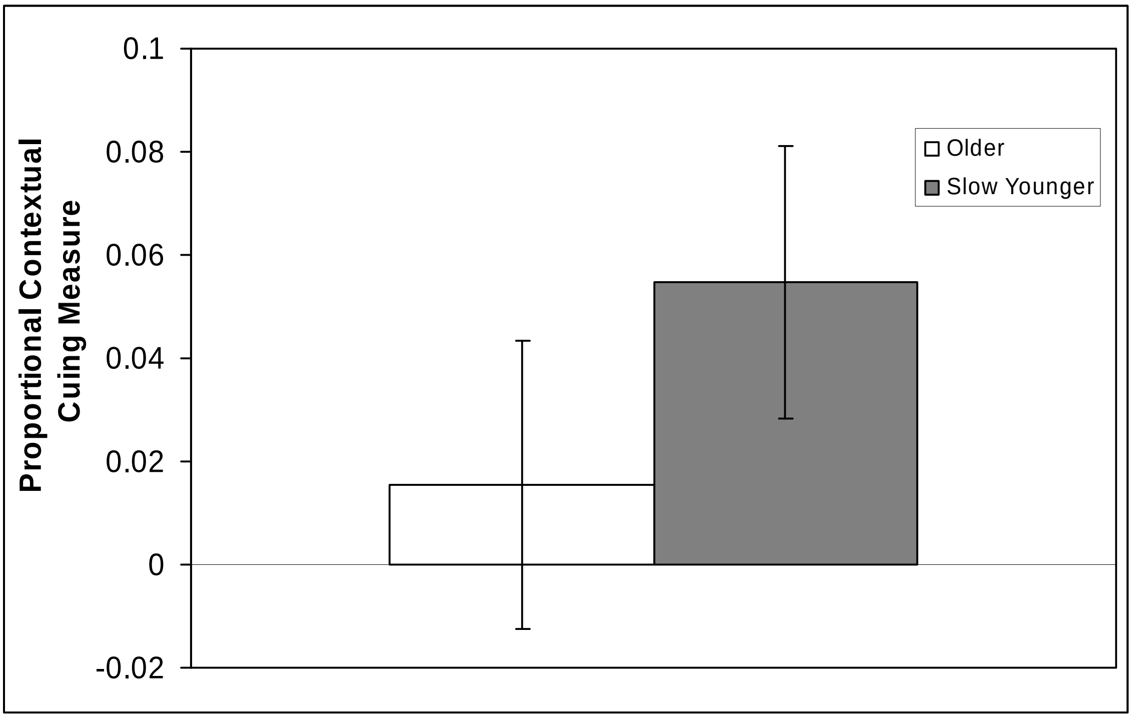


Figure 3.5. **Mean proportional measure of contextual cuing across participant groups in Experiment 3; error bars represent standard error.**

Additionally, the longer detection task included in this experiment in an attempt to replicate findings of contextual cuing in older adults by Howard et al. (2004), did not facilitate contextual cuing, since there was no difference between the levels of cuing shown by older participants in Experiment 1, who received only 16 blocks of trials, and the Older group in this study after 30 blocks of trials, $t(48) = 0.63$, $p > .5$. Although the Slow Younger participants received twice as many trials during the detection task, their cuing score was almost half of younger participants in Experiment 1; however, this difference was not reliable, $t(48) = 1.07$, $p > .28$.

In an attempt to relate a measure of processing speed to contextual cuing ability, we correlated performance on the Digit Symbol Coding Task and the proportional cuing score.

This correlation was weak and non-significant both in the group as a whole, $r = -.03$, $p > .8$, and when examined using just data from the Older participants, $r = .03$, $p > .8$. This relationship was more substantial and marginally significant in the Slow Younger group, $r = -.36$, $p = .05$, though seemingly in the opposite direction to that predicted by Processing Speed theory since faster response speed is related to higher scoring on the Digit Symbol Coding Task. Though upon further inspection, this relationship may be explained by the fact that amount of tailored offset manipulation applied to the distracter stimuli was dictated by participants' response speed, so faster participants experienced a heavy response speed calibration manipulation (i.e., they viewed more heavily offset distracter letter stimuli) which most likely resulted in less contextual cuing transpiring (Elizabeth Maylor, personal communication, November 17, 2009).

We also correlated the standardised memory measures (Table 3.1) collected from all participants and the proportional cuing score. However, none of these correlations achieved significance in the Slow Younger group (r's > -0.27, p's > .16). In the Older group, there was a negative correlation between the Digit Span measure of working memory and proportional cuing, $r = -0.41$, $p < .03$, somewhat surprisingly indicating that higher working memory capacity coincided with lower contextual cuing. All of the other correlations with the WMS-III measures of memory were weak and non-significant, r's > -0.27, p's > .25.

3.2.2.2 Reported Awareness Results

The longer task length also resulted in a higher rate of reported awareness in this experiment overall, with 23 Older participants (77%) and 29 Slow Younger participants (97%) answering that they picked up on the repetition of configurations. Seven (30%) Older and 4 (14%) Younger of these aware individuals reported using a memorisation strategy after the repetition became apparent. The mean onset of awareness occurred at block 12 of the task for Slow Younger participants and block 9 of the task for Older participants, $t(50) = 1.59$, $p > .11$. However, reported awareness did not seem to help these participants to perform better in the task, since there was no interaction between Awareness and Repetition nor a three-way Repetition x Epoch x Awareness interaction when performance was re-analysed in each age group and segmented by awareness, all F's < 2.07, all p's > .16.

3.2.2.3 Generation Task

Results from the generation task are presented in Figure 3.6, and were analysed using a repeated-measures ANOVA with Repetition (Repeated vs. Non-Repeated) and Block (1-4) as within-subjects variables and Age (Slow Younger or Older) as a between-subjects variable. Participants did not show a main effect of Repetition overall, $F(1, 58) < 1$, meaning that there was no difference in generation accuracy between Repeated and New configurations. There was also no Repetition x Age interaction, $F(1, 58) < 1$, or main effect of Age, $F(1, 58) = 3.40$, $p > .07$, to suggest divergent performance between Older and Slow Younger participants, and this was verified further by individual ANOVAs of the Slow

Younger and Older data with neither group showing a main effect of Repetition nor a Repetition x Block interaction, all *F*'s < 1.

There was a change in generation accuracy as the task progressed, as shown by a main effect of Block, $F(3, 174) = 5.48$, $p < .001$, but a significant Block x Age Group interaction, $F(3, 174) = 5.16$, $p < .002$, implies that the pattern of change was different between Slow Younger and Older adults. Post-hoc tests compared generation accuracy for Repeated configurations in each block to performance at chance level (25%), which is indicative of no awareness. In Older adults, performance never exceeded chance performance, all *t*'s < 1.02, *p*'s > .31, and there were never differences in accuracy between Repeated and Non-Repeated configurations, all *t*'s < 0.78, *p*'s > .51. Generation accuracy for Repeated configurations did exceed chance level in Block 4 of the task for Younger participants, $t(29) = 2.47$, p < .02; all other *t*'s < 1.70, *p*'s > .10; however, a pairwise comparison between Repeated and Non-Repeated accuracy in Block 4 showed no difference in performance, $t(29) = 0.17$, $p > .86$; all blocks *t*'s < 1.10, *p*'s > .28. These findings imply that conscious awareness of contextual cuing knowledge was not present in either participant group.

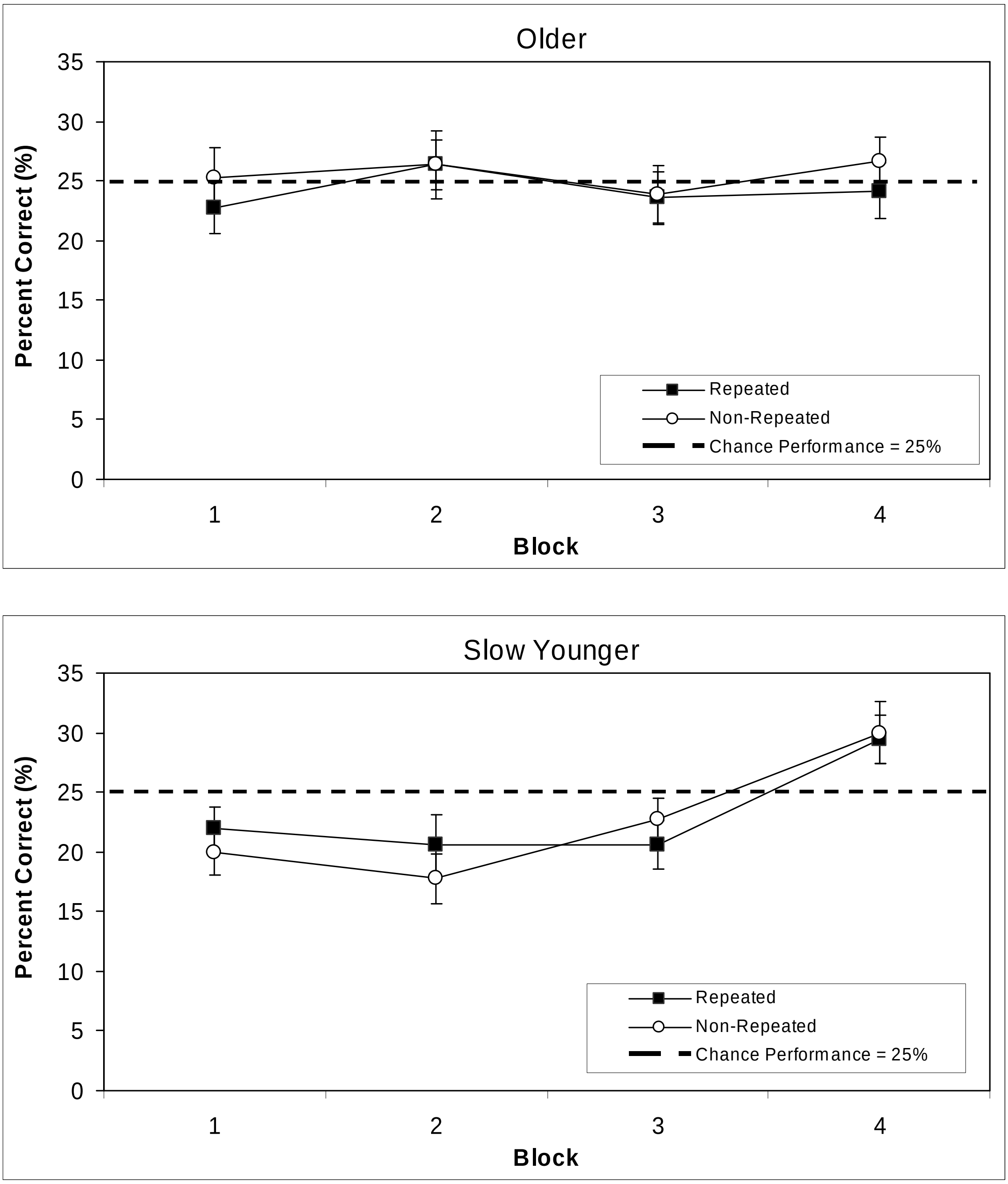


Figure 3.6. **Generation performance for Older and Younger participants for Repeated and Non-Repeated configurations as compared to chance performance (25%); error bars represent standard error of the mean.**

3.2.3 Discussion

This experiment aimed to address the concerns raised by Experiment 1 that the contextual cuing impairments in older adults may have been caused by cognitive slowing. We were able to closely match younger participants' response speed to the slower response times demonstrated by the older participants in this experiment by altering the letters so as to increase the similarity between the target and distracter letters according to each younger participant's initial baseline response speed.

The results of this experiment do not provide convincing evidence that slow response speeds produce equivalent levels of contextual cuing in Older and Slow Younger participants. The results of the ANOVA suggested that contextual cuing was absent in the Slow Younger group. However, further comparisons of Slow Younger participants' proportional cuing scores to zero showed evidence of significant cuing. Neither the ANOVA nor the analysis of proportional cuing gave a clear indication that contextual cuing occurred in Older participants. Although collectively these findings suggest that the display manipulations in this experiment impeded Slow Younger participants' performance to some degree in relation to Younger participants in Experiment 1 (though not statistically), we maintain that these results also imply that the letter stimulus modifications in this experiment and Experiment 2 did not adequately simulate the specific processing impediments experienced by older participants.

Experiment 3 employed a 30 block detection task identical in design to that of Howard et al. (2004) to see if a longer task produced contextual cuing in older participants. Although the marginal main effect of Repetition obtained in the individual analysis of Older participants' data could be taken as an indication that some participants may have developed more efficient responding for Repeated configurations, all follow-up tests showed no indication that implicit contextual cuing occurred at a group level in the older participants. This result was not only a failure to replicate the findings of Howard et al. (2004), but also undermines our original assumption that older adults would eventually show learning when given more detection trials. These findings, in conjunction with the fact that proportional cuing scores also remained low or negative for all of the older adults in Experiments 1 and 3, suggest that older populations show little, if any, contextual cuing effect at all, or at least with the amounts of exposure used here.

A closer examination of a follow-up awareness analysis in Howard et al. (2004) supplied some insight into how an overall contextual cuing effect was obtained for older participants in their study. Fifteen older participants (42% of the total group) verbally reported awareness of the display repetition critical to the contextual cuing paradigm, and subsequently a separate analysis of learning was performed on this sub-group which revealed that these participants failed to show evidence of contextual cuing. This analysis was included to imply that reported awareness may have interfered with these older participants' contextual cuing performance, but it also exposed the fact that a contextual cuing effect was not present in a large portion of the older group included in Howard et al.'s (2004) study. Therefore, the presence of a contextual cuing effect may have been caused by a small group of older participants who showed exceptional levels of implicit contextual cuing.

Additionally, a statistical relationship between processing speed and contextual cuing was only evident in the younger group, and even then it suggested actually that faster processing speed hindered cuing. Although it would be tempting to conclude that older adults' contextual cuing decrements are not a product of general perceptual slowing, perhaps slower response speed exacerbates other cognitive deficits that are inherent to ageing.

3.3 Experiment 4

Although slow younger participants in Experiments 2 and 3 did not show evidence of contextual cuing decrements, this does not necessarily mean that the slower processing speed found in Older participants in Experiment 1 played no role in the deficits they showed. Instead, it is possible that slower response speed interacts with other cognitive deficits that occur with age. In Experiment 4 we examined older adults' contextual cuing performance under conditions that promoted faster response speeds.

If slower responding has an age-specific involvement in impairing contextual cuing, we would expect older participants' learning deficits to be abolished or at least attenuated when response speed mimics that of younger adults. In contrast, similar levels of contextual cuing in fast older and naturally slower old adults would suggest that processing speed is not the critical factor and would implicate the involvement of another age-specific cognitive impairment.

3.3.1 Method

3.3.1.1 Participants

Twenty-five older participants (*M* = 66.72, *SD* = 6.82) were recruited specifically to take part in this experiment, using an advertisement at an adult education centre, and paid £15 for their time. All of these participants were in good health, free from diagnoses of neurological disorders, and assigned to the Easy Detection group (*n* = 20), while the data from the Older group of participants in Experiment 3 were included in all analyses as a control group and will be referred to as the Difficult Detection Older group (*n* = 30). The Easy Detection Older group viewed more distinctive distracter stimuli (Ss instead of Ls) in an attempt to speed up their responses. The 2 groups of older participants were matched for age, education, and on most of the subscales of the WMS-III tests of memory and intelligence shown in Table 3.2, all *t*'s < 1.39, *p*'s > .17. The Easy Detection Older group scored higher on the second Logical Memory Recall subscale, $t(48) = 2.66$, $p < .01$, and marginally better on the Vocabulary subscale, $t(48) = 1.90$, $p = .06$.

Table 3.2. **Participant Demographics in Experiment 4**

	Difficult Detection Older (n = 30)	**Easy Detection Older** (n = 20)
Gender		
Female	20	15
Male	10	5
Age	M = 67.65 (7.47)	M = 65.20 (5.57)
Education (years)	M = 14.63 (2.27)	M = 14.20 (1.77)
Memory		
WMS-III Logical Memory I Recall	M = 34.70 (9.83)	M = 38.20 (9.67)
WMS-III Logical Memory II Recall	M = 21.33 (6.62)	M = 26.50* (6.86)
WMS-III Logical Memory Recognition	M = 25.40 (2.49)	M = 25.35 (3.28)
WMS-III Logical Memory Retention	M = 85.11 (17.45)	M = 86.50 (11.45)
Adult Intelligence Scale		
Vocabulary	M = 47.87 (13.46)	M = 54.35 (8.62)
Digit Span	M = 17.97 (3.06)	M = 19.45 (4.52)
Digit Symbol Coding Task	M =61.60 (14.93)	M =63.85 (14.27)

Numbers in brackets denote standard deviations.
* $p < .01$

3.3.1.2 Design

This version of the detection task was a 2 x 2 x 6 (Task Difficulty x Repetition x Epoch) mixed-factorial design, with Detection Task Difficulty (Easy or Difficult) manipulated between-subjects, and Repetition (Repeated and Non-Repeated) and Epoch (1-6) manipulated within-subjects. Following the detection task, participants undertook a 2 x 2 x 4 (Detection Task Difficulty x Repetition x Block) mixed-factorial design generation task, with Detection Task Difficulty (Easy or Difficult) as a between-subjects variable, and Repetition (Repeated and Non-Repeated) and Block (1-4) a within-subjects variables. The generation task measured participants' awareness of the Repeated configurations shown during the detection task by assessing accuracy in providing the region of the display which the now "missing" target letter appeared in during the detection task.

3.3.1.3 Materials and Apparatus

The instructions and procedure described in Experiment 2 for creating and presenting all of the configurations of letters were also used for this experiment. The detection task was extended from 16 to 30 blocks of trials (from 4 to 6 epochs). All participants were still required to search for a letter T, but for the Easy Detection Older group this target letter now appeared amongst 11 letter S's as distracters instead of L's.

A generation test was used to measure awareness was identical the one used in Experiment 3; however, all of the configurations now appeared with the T's replaced by S's in the Easy Detection Older group.

3.3.1.4 Procedure

The experiment began with the administration of the Logical Memory I scale of the WMS-III. The remainder of the memory tests shown in Table 3.2 were given upon completion of the detection and generation tasks (approximately 60 minutes later). The detection task progressed exactly as in Experiment 1, starting with instructions to participants to locate the T in the configuration using the arrow keys followed by on-screen examples of a configuration and the new offset letter stimuli. After 6 practice trials participants continued with the detection task as in Experiment 1, which was followed by the awareness questionnaire.

Immediately after the self-report awareness measure, participants received the generation task. At the end of the task, participants were informed of their accuracy, and they were administered the remaining subscales of the WAIS. The duration of the experiment was roughly 2 hours.

3.3.2 Results

3.3.2.1 Detection Task

An ANOVA with Repetition as a within-subjects variable (Repeated versus Non-Repeated) and Group (Difficult Detection Older or Easy Detection Older) as a between-subjects variable was conducted on accuracy data in the detection task.). There was no main effect of Group, $F(1, 48) = 1.29$, $p > .26$, indicating that both groups of older participants demonstrated high response accuracy overall (Difficult Detection Older, M = 99%, SE = 0.10; Easy Detection Older, M = 100%, SE = 0.11). Furthermore, response accuracy was also similar for Repeated and Non-Repeated configurations overall and within each participant group during the detection task (Difficult Detection Older, Repeated, M = 99%, SE = 0.15; Non-Repeated, M = 99%, SE = 0.11; Easy Detection Older, Repeated, M = 100%, SE = 0.14; Non-Repeated, M = 99%, SE = 0.16), with neither the main effect of Repetion, $F(1, 48) = 0.12$, $p > .73$, nor a Repetition x Group interaction, $F(1, 48) = 0.13$, $p > .86$, approaching significance in the ANOVA.

Repeated-measures ANOVA was used to compare detection latencies between the groups (shown in Figure 3.7), and included Repetition (Repeated and Non-Repeated) and Epoch (1-4) as within-subjects variables and Detection Task Difficulty (Easy or Difficult) as a between-subjects variable. There was a main effect of Task Difficulty on RTs, meaning that altering the distracter letters within the visual search displays produced faster responses in the Easy Detection Older group (Difficult Detection Older, M = 3178 ms, SE = 131; Easy Detection Older, M = 842 ms, SE = 44), $F(1, 48) = 180.85$, $p < .001$.

All participants showed an improvement in baseline response speed across the task, as evidenced by the main effect of Epoch (Epoch 1, M = 2598 ms, SE = 207; Epoch 6, M = 1990 ms, SE = 158), $F(5, 240) = 40.86$, $p < .001$. However, there was also an Epoch x Task Difficulty interaction, $F(5, 240) = 17.88$, $p < .001$, indicating a ceiling effect in the amount of motor efficiency that could be achieved in the Easy Detection Older group (M = 182 ms, SE = 45) compared to the Difficult Detection Older group (M = 882 ms, SE = 108). Most importantly, the ANOVA showed no indication that contextual cuing occurred at a group level, as neither the main effect of Repetition, $F(1, 48) = 2.61$, $p > .11$, nor the Repetition x Epoch interaction, $F(5, 240) < 1$, were significant. Though the Repetition x Task Difficulty interaction was marginally significant, $F(1, 48) = 3.53$, $p = .07$, there was no further evidence of performance differences between groups as the Repetition x Epoch x Task Difficulty, $F(5, 240) < 1$, interaction was not significant. The latter result was consistent with a follow-up ANOVA comparing RT performance between configurations and between groups in the last epoch of the task, which showed neither a main effect of Repetition nor a Repetition x Task Difficulty interaction, *F*'s < 1.15, *p*'s > .28. Individual comparisons of Repeated and Non-Repeated RTs in each epoch for each participant group also confirmed that contextual cuing was not evident at any point in the task, since the only difference that approached significance was a response advantage for Non-Repeated configurations, *t*(19) = 1.88, *p* > .07, in the third epoch in the Easy Detection Older group, all other *t*'s < 1.60, *p*'s > .12.

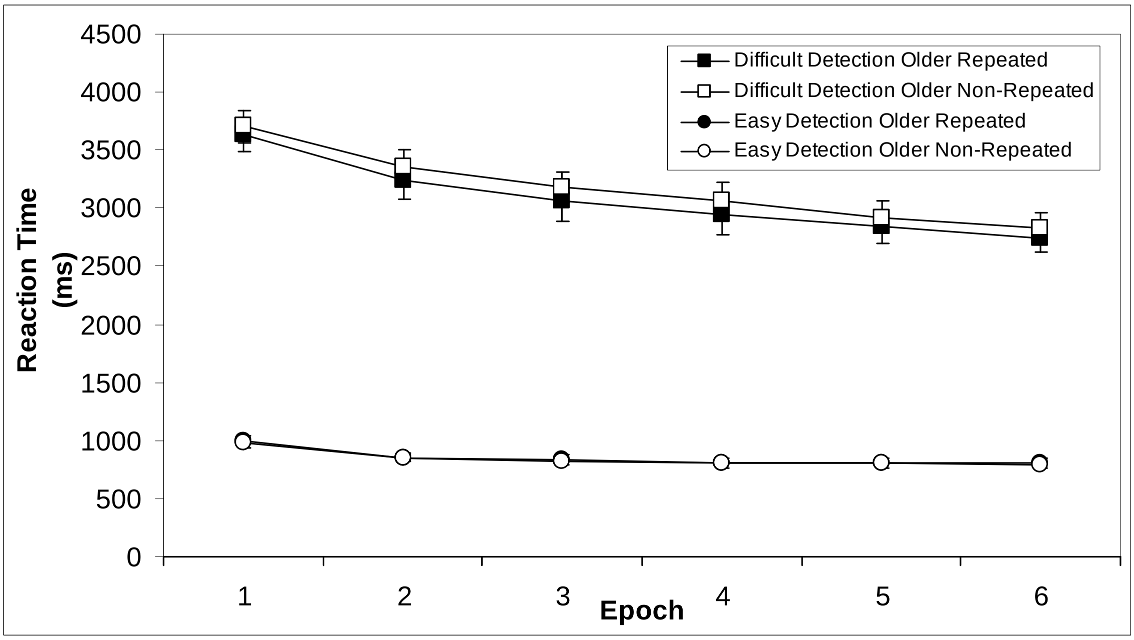


***Figure 3.7.* Means of the median reaction times (ms) for Difficult Detection Older participants and Easy Detection Older participants, in Experiment 4; error bars represent standard error of the mean.**

Perhaps changing the distracter letters to S's to make RTs in the Easy Detection Older group faster also changed the nature of visual search during the detection task, because the target letter was so easily visible within each display. It is also possible that since Easy Detection Older participants were already responding very quickly at the beginning of the task, there was little potential to develop further efficiency for Repeated displays. Therefore, a group of younger participants (n = 18) were given this version of the detection task to examine whether contextual cuing was still possible under these visual conditions. These younger participants responded even faster than the Easy Detection Older participants (M = 543 ms, SE = 17), $t(36) = 6.15$, $p < .001$. An ANOVA of the younger group's data also showed a significant main effect of Epoch, $F(5, 85) = 6.54$, $p < .001$, and more importantly, a main effect of Repetition, $F(1, 17) = 13.91$, $p < .002$, confirming that contextual cuing can still occur under these faster response conditions. The Repetition x Epoch interaction was not significant, $F < 1$, but a non-significant contextual cuing effect in the first epoch, $t(17) = 1.87$, $p = .08$, became highly significant by the last epoch, $t(17) = 3.11$, $p < .007$.

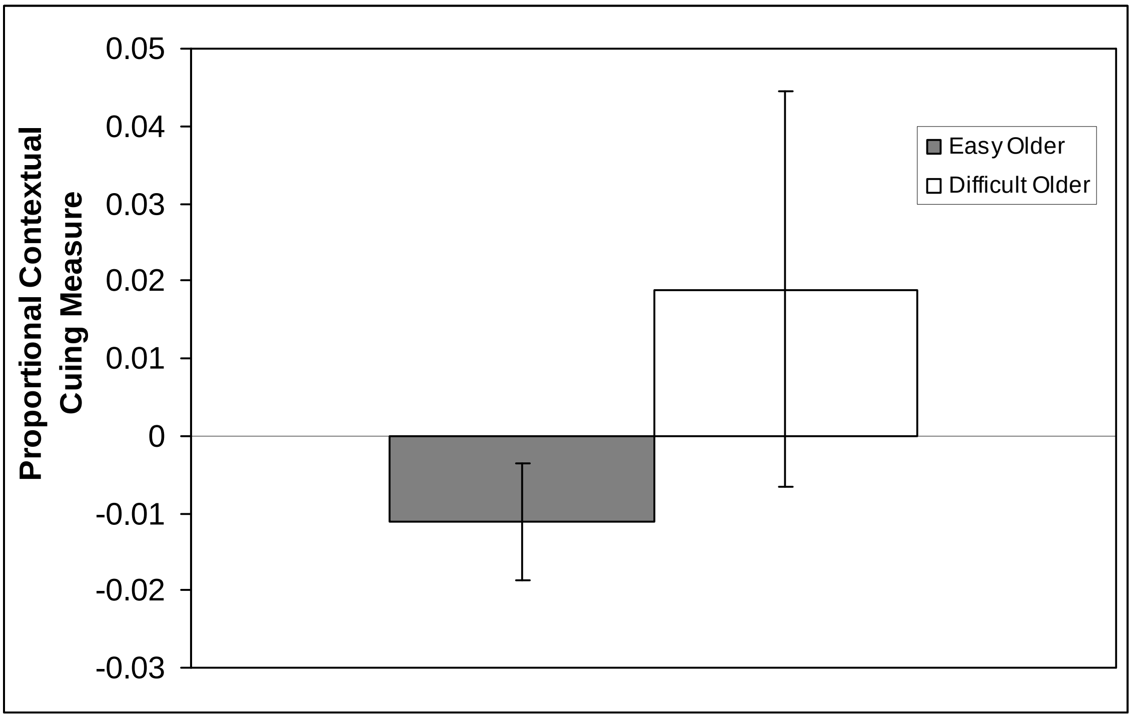


Figure 3.8 **Mean proportional measure of contextual cuing across older participants in the Easy Detection and Difficult Detection groups in Experiment 4; error bars represent standard error.**

The proportional analysis of cuing performed in the previous experiments was also carried out on this dataset, but consistent with the overall ANOVA, neither the Difficult Detection Older nor the Easy Detection Older group's cuing score was statistically greater than zero, t's < 1.47, p's > .15. If anything, Figure 3.8 shows that the Easy Detection Older participants learned less, although not reliably, than the Difficult Detection Older participants on the contextual cuing task, $t(48) = 0.94$, $p > .30$.

We also examined whether processing speed was related to the amount of contextual cuing the Easy Detection Older participants showed by correlating their proportional measure of cuing to their Digit Symbol Coding Task score (Table 3.2). This relationship was weak and non-significant, $r = .22$, $p > .34$, providing further evidence that older adults' slowed processing is not responsible for their impaired performance on this task.

In Experiment 3, we obtained a negative correlation between the Digit Span measure of working memory and the proportional measure of cuing in the Difficult Detection Older group, $r = -.41$, $p < .03$. No such relationship was shown in the Easy Detection Older group, $r = -.01$, $p > .95$, though we did find that these participants' proportional cuing scores were positively related to their performance on the Recognition sub-scale of the WMS-III, $r = .53$, $p < .02$. No other reliable statistical relationships were observed between cuing and the other standardized measures of memory in these individuals, p's > .19.

3.3.2.2 Reported Awareness Results

Fourteen Easy Detection Older participants (70%) and 23 Difficult Detection Older participants (77%), $\chi^2 = 0.28$, $p > .59$, reported noticing the repetition of configurations, with awareness occurring at blocks 9 and 8 respectively, $t(35) = 0.56$, $p < .57$. Nine of the 23 (39%) Difficult Detection Older aware individuals said they used a memorization strategy after the repetition became apparent, while only one of the Easy Detection Older aware individuals reported use of this strategy. ANOVAs were performed in each group of older participants with Awareness (Aware or Unaware) included as an additional between-subjects variable, but showed no significant interactions with this variable, all F's < 1. This leads us to conclude that noticing the repetition manipulation did not produce a contextual cuing advantage.

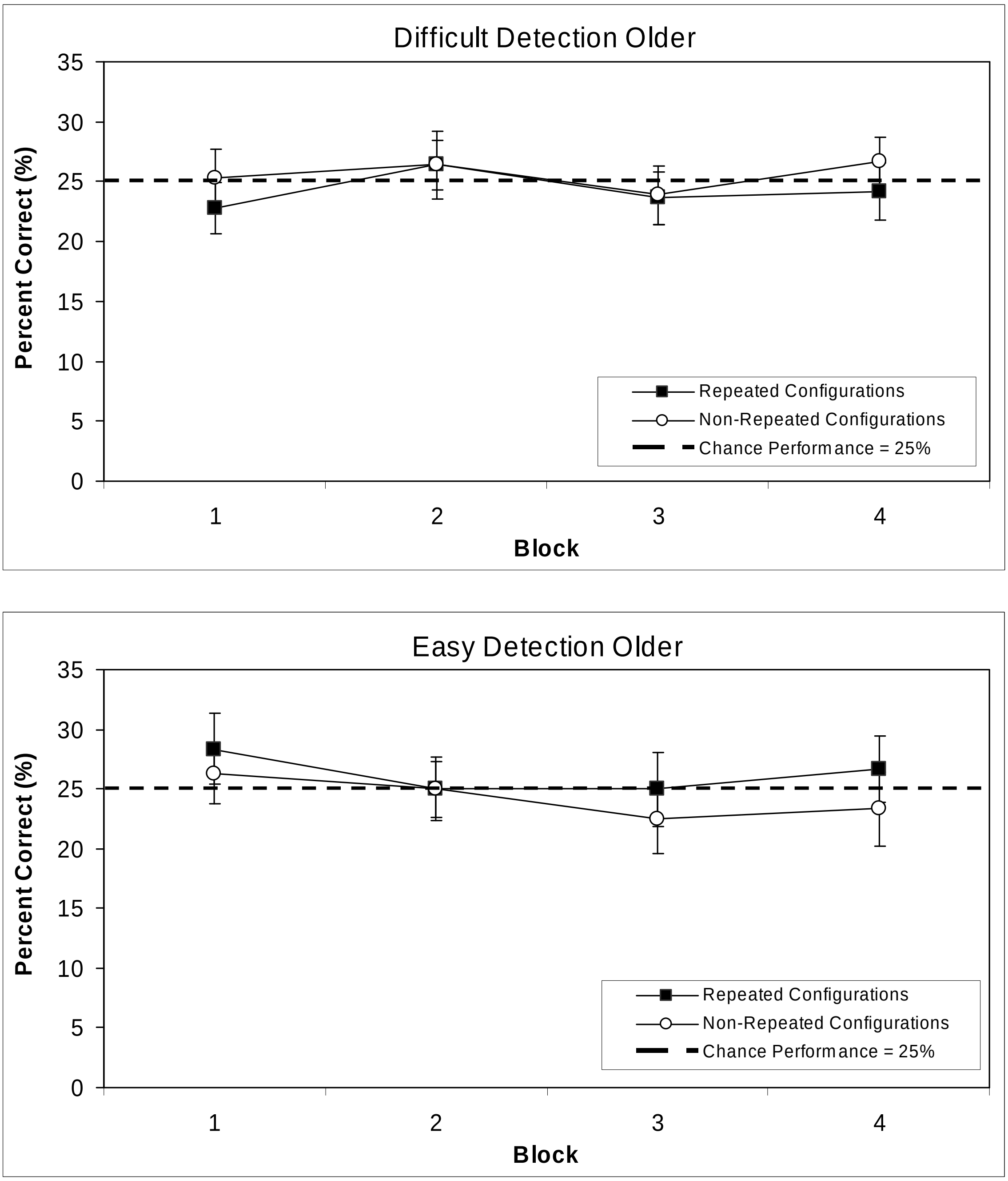


Figure 3.9. **Generation performance for Difficult and Easy Detection Older participants for Repeated and Non-Repeated configurations as compared to chance performance (25%); error bars represent standard error of the mean.**

3.3.2.3 Generation Task

In a repeated-measures ANOVA of generation performance (shown in Figure 3.9) we included Task Difficulty (Easy or Difficult) as a between-subjects variable and Repetition (Repeated and Non-Repeated) and Block (1-4) as within-subjects variables. There was no main effect of Repetition, $F(1, 58) < 1$. There was also no main effect of Block or interaction between Repetition and Block, all *F*'s < 1. The ANOVA showed no interactions with Task Difficulty, suggesting no differences in performance between the Easy and Difficult Detection Older groups, all *F*'s < 1.55, *p*'s > .22. Performance which exceeds the level of success dictated by chance (25% accuracy) could also indicate that participants were consciously aware of configuration information; however, neither group showed evidence of successful generation ability when task performance was compared with chance, all *t*'s < 1.32, *p*'s > .20.

In sum, the data show that detection task difficulty did not affect performance, since neither group of older participants showed evidence of contextual cuing or generation ability.

3.3.3 Discussion

In this version of the task, we altered the distracter letters to simulate the faster baseline response speed of younger adults in an ageing population. Although the Easy Detection Older participants responded much faster than the Difficult Detection Older controls, they still did not show a contextual cuing effect. Indeed, the proportional cuing scores of Easy Detection Older participants in this experiment were reliably lower than those of the Younger participants in Experiment 1 and (younger) Control participants in

Experiment 2, t's > 2.52, p's < .01, despite the fact the Easy Detection Older participants received almost twice as many detection trials.

Modifying the detection task to make it easier was successful in eliciting faster responses in Easy Detection Older participants, but it raises the concern that the new combination of stimuli produced a pop-out effect for the target stimulus. If this occurred it could be considered an alternative explanation for the absence of a contextual cuing effect in Easy Detection Older participants, since performance on the task would no longer require directed visual search. There was also the possibility that the overall speed of responding was so fast to begin with that it left little opportunity for developing significant response improvement to Repeated displays. However, it is unlikely that the nature of the task changed qualitatively or that there was a ceiling effect in overall response times in the Easy Detection Older group, since a contextual cuing effect was elicited in a group of younger participants who showed faster RTs when given the easier version detection task

From these results it is clear that slow responding was not the source of the learning impairments shown by slower older adults in Experiment 1 and the Difficult Detection Older participants in this experiment, but rather that older adults experience other age-specific cognitive limitations which interfere with their ability to learn about the contextual cues available in the detection task.

All older participants showed poor ability to generate target information in the awareness test. This finding is not surprising considering that no evidence of learning emerged in the detection task itself. In addition, the presence of recognition ability in younger adults in Experiment 1 and of a positive statistical association between performance on the Recognition sub-scale of the WMS-III and the proportional measure of cuing and of a positive statistical association between performance on the Recognition sub-scale of the WMS-III and the proportional measure of cuing suggests there may be an association between the implicit contextual cuing effect and explicit recognition ability.

Therefore, this experiment demonstrates that neither inducing the faster baseline response speed of younger adults in an ageing population, nor extending the detection task, yielded learning in these older adults.

3.4 Discussion of Experiments 2-4

In this chapter, we pursued a processing speed explanation of older adults' impairments by altering the properties of the stimuli in the displays shown to both younger and older participants in order to slow down or speed up response latencies.

Slower response latency in older participants seemed to coincide with the impairments they demonstrated in the contextual cuing task. In Experiments 2 and 3, we investigated the idea that cognitive slowing may account for older adults' impairments by seeing how contextual cuing changed in younger participants when the display properties required more effortful responding. In Experiment 2, we investigated the idea that cognitive slowing may account for older adults' impairments by seeing how contextual cuing changed in younger participants when the display properties required more effortful search. While the offset and contrast display manipulations induced markedly higher response times than the Control group, only the Offset group's speed of responding approximated the levels of Older participants in Experiment 1. Although younger participants' responses in the Offset group could be successfully "aged" in speed, comparable levels of contextual cuing were shown between groups regardless of response speed.

Slow Younger participants in Experiment 3, who experienced customized amounts of the offset to alter their response speed more precisely, showed some evidence of contextual cuing decrements in relation to the younger participants from Experiment 1. However, comparisons of the proportional contextual cuing measure showed that the Slow Younger participants still outperformed Older participants on the detection task in Experiment 3. From this we concluded that processing speed may not provide a general explanation of impairment in learning overall, but could still play a role in contextual cuing in older adults.

In Experiment 4, we asked whether "youthful" (i.e., faster) older participants would be able to overcome some of the contextual cuing deficits they exhibit normally. Despite their faster response times, the Easy Detection Older participants still demonstrated contextual cuing impairments that were identical to those seen in the naturally slower Difficult Detection Older group (whose performance replicated that of the Older group in Experiment 1).

Salthouse (1991; 1996) has proposed an extreme argument for cognitive slowing, the Processing Speed Theory, which argues that standardized measures of perceptual speed can explain most of the age-related variance in performance on many cognitive tasks. Subsequent studies by Salthouse and colleagues have found substantial evidence in favour of this parsimonious explanation of age-related differences for many aspects of cognitive functioning (Salthouse & Babcock, 1991; Fristoe et al., 1997; Salthouse, Atkinson, & Berish, 2003; Tucker-Drob & Salthouse, 2008); however, this theory has not been applied extensively to older adults' performance on implicit memory tasks (but see Salthouse et al., 1999). If processing speed can account for the contextual cuing deficits shown by older adults in Experiment 4, we would have expected to find a relationship between measures of contextual cuing and a standard index of processing speed like the Digital Symbol Coding Task. Such relationships were not observed.

Chun and Phelps (1999) found that artificially slower younger participants still outperformed slower amnesics with general hippocampal and temporal lobe damage in the task, which prompted them to conclude that these brain structures are vital to performance and that processing speed was not a factor in contextual cuing. That pattern is therefore similar to the one observed here for the effects of ageing. In contrast Manns and Squire (2001) found that slower hippocampal amnesic participants showed intact learning, and amnesic participants with more extensive damage to the medial temporal and lateral temporal lobes were impaired on the task but were not slower in relation to controls. Most importantly, they also found that inducing slower responding in younger participants produced behaviour akin to the unimpaired hippocampal amnesics, which led them to conclude that slowing aided contextual cuing. Our findings are not inconsistent with either of these studies, in that both found a substantial cuing effect in artificially slower participants. However, our results point to a similar conclusion to that of Chun and Phelps (1999), namely that lower levels of contextual cuing in older individuals may be linked to impaired medial temporal lobe functioning rather than their slower speed of responding.

There were also some superficial differences between Experiment 1 and the design and participant make-up of participants in Howard et al.'s Experiment 1 that could potentially account for the disagreement in results. The British participants in Experiments 1 and 3 had fewer years of formal education in relation to the American participants in Howard et al. (2004) [Experiment 1, M = 13.55, SD = 2.39; Experiment 3, M = 14.63, SD =

2.27; Experiment 4, Easy Detection Older, *M* = 14.20, *SD* = 1.77; Howard et al. (2004) Experiment 1, *M* = 17.22, *SD* = 5.61], which is probably due to the shorter length of the UK education system in relation to the American education system. Individual differences in level of education and other forms of crystallized intelligence have been shown to relate directly to the severity and rate of cognitive decline with age (Birren & Morrison, 1961; Heaton, Grant, & Matthews, 1986; Kaufman, Reynolds, & McLean, 1989), so this seems a relevant source of our participants' poor contextual cuing. That being said, the older adults included in Experiments 3 and 4 in this thesis also scored higher than the older adults in Experiment 1 of Howard et al. (2004) on the standardised vocabulary measure [Experiment 3, *M* = 47.87, *SD* = 13.46; Experiment 4, Easy Detection Older, *M* = 54.35, *SD* = 8.62; Howard et al. (2004) Experiment 1, *M* = 35.58, *SD* = 7.59], yet still showed no sign of being able to learn in the contextual cuing task.

The slight differences in the appearance of stimuli between the experiments in this thesis and those in Experiment 1 of Howard et al. (2004) also merit discussion. First of all, the stimuli presented to participants in Howard et al.'s study were uncoloured. The stimuli in Experiment 1 were based on those shown in Chun and Jiang's first contextual cuing experiments (Chun & Jiang, 1998; 2003) where the stimuli appeared in colour. Howard et al. also included a slight offset manipulation for distracter letters, which they argued would enhancing contextual cuing (e.g., Chun & Phelps, 1999). Considering the results of Experiment 1, this assumes that the colour manipulation we included hindered contextual cuing in our older participants. It is possible that the extra colour information creates more cognitive load during encoding and causes lower quality representations to be formed; however this is not likely to be the case, since the contextual cuing task in Experiment 3 was a direct replication of that of Howard et al. (2004), and these participants did not view coloured stimuli and received a slight letter offset but still demonstrated little or no ability to show contextual cuing.

Our failure to replicate the significant learning effect found in Howard et al. (2004) also challenges the popular notion that explicit memory is impaired while implicit forms of memory remain intact in cognitive ageing (Fleischman, 2007). Moreover, the presence of recognition ability in younger participants in Experiment 1 questions the purely implicit nature of the contextual cuing task. It bears mentioning that older adults' logical memory scores in Experiment 1 were also much lower than those of older participants' from Howard et al. (2004) [Experiment 1, *M* = 28.60, *SD* = 15.10; Howard et al. (2004) Experiment 1, *M* = 38.97, *SD* = 25.11]. It is possible therefore that contextual cuing in older adults is impaired simply because this sort of processing requires explicit memory resources. While we are not able to determine the specific cause of the deficits older participants show in the contextual cuing task from these findings alone, it is still implied that the mechanism behind these deficits in learning is intrinsic to cognitive ageing.

4 Awareness in Contextual Cuing

The previous chapter approached age-related differences in contextual cuing by examining other resulting differences in performance as a possible explanation of older adults' impairments. Not only did younger participants respond much more quickly than older adults in the contextual cuing task, as demonstrated extensively in Chapter 3; but they also exhibited the ability to consciously retrieve acquired information on explicit tests (Chapter 2). In the present chapter, the perspective shifts from analyzing the factors of cognitive slowing hypothesized to lead to older adults' poor contextual cuing to looking more closely at the possible sources of successful contextual cuing ability in younger adults.

Younger participants show facilitation for displays they have been exposed to repeatedly during a visual search task, which indicates that they have acquired some sort of mental representation of these displays that they rely upon to aid their search. However, in the majority of previous research, they do not show evidence of being able to consciously use these representations to support performance during a recognition (Barnes et al. 2008; Chun & Jiang, 1998; 1999; Chun & Phelps, 1999; Howard et al., 2004; 2006; Huang, 2006; Manns & Squire, 2001; Nabeta, et al., 2003; Pollman & Manginelli, 2009; Schankin & Schubo, 2009; van Asselen et al., 2009) or generation test (Bennett et al., 2008; 2009; Chun & Jiang, 2003; Park et al., 2004). This dissociation between unconscious learning and conscious retrieval has led researchers to conclude that the contextual cuing phenomenon reveals the existence of a purely implicit processing mechanism.

Despite finding a lack of awareness on an explicit recognition test, Greene et al. (2007) obtained imageing data showing that participants recruited the hippocampus when performing a contextual cuing task. Such a result implies that neural structures thought to support only conscious or declarative processing (Squire, 1992) may be operating on implicit contextual cuing knowledge even when awareness is absent. However, the null effect in the recognition test in Greene et al. may simply be an artefact of low power and sensitivity. Contextual cuing in Experiment 1 was accompanied by an awareness effect in younger adults when a modified recognition test was used, while older adults showed neither significant contextual cuing nor awareness. This leads us to question whether existing measures of awareness in contextual cuing experiments are accurate gauges of conscious processing.

In the following experiments, we focus on the awareness effect that accompanied contextual cuing in younger adults in Experiment 1. In order to address the possibility that the informational source of contextual cuing may actually be accessible to explicit memory retrieval processes, we examined the power and reliability of existing measures of awareness used in contextual cuing experiments, the motivational influence of including an incentive for accurate performance in the explicit test, as well the magnitude of awareness when measured after varying lengths of the detection task and degrees of contextual cuing.

The presence of awareness in these experiments would conflict with the idea that implicit knowledge is functionally distinct and inaccessible to conscious processing as proposed in dual-systems theories of memory. Therefore, perhaps it would be more appropriate to characterize the memory decrements that occur in healthy ageing as a general memory loss, rather than as impairments specific to consciousness at the time of processing.

4.1 Experiment 5

Younger participants in Experiment 1 demonstrated evidence of possessing awareness for contextual cuing information by performing above chance on a recognition task. The recognition task in that experiment included twice the number of explicit trials traditionally used in previous versions of the task where participants did not show significant recognition ability ((Barnes et al. 2008; Chun & Jiang, 1998; 1999; Chun & Phelps, 1999; Howard et al., 2004; 2006; Huang, 2006; Manns & Squire, 2001; Nabeta, et al., 2003; Pollman & Manginelli, 2009; Schankin & Schubo, 2009; van Asselen et al., 2009). Yet there have been several demonstrations of reliable recognition using the original shorter task design of the recognition test (Brockmole & Henderson, 2006; Endo & Takeda, 2005; Olson & Jiang, 2004; Olson et al. 2005; Ono et al., 2005; Peterson et al., 2002; Preston & Gabrieli, 2008; Vaidya et al., 2007), which tend to be ignored in discussions of the implicit nature of the task in the contextual cuing literature. Although these findings, in conjunction with the presence of awareness in Experiment 1, are potentially challenging to the claim that contextual cuing is implicit, previously discussed criticisms of recognition tests as a measure of awareness are still relevant.

In the present experiment, we used the same 24 block detection task included in Chun and Jiang (2003), but extended the generation task they employed from 24 trials to 96 to examine whether the contextual knowledge learned during experiments in contextual cuing is only accessible to implicit processes. If younger participants in past experiments did actually have explicit access to contextual knowledge from the detection task, we would expect to see an ability to generate target locations emerge with the introduction of more trials in the generation task. Such a result would lead us to conclude that previous null explicit results in generation tasks (Bennett et al., 2008; 2009; Chun & Jiang, 2003; Park et al., 2004) can be attributed to inadequate probing for explicit knowledge in those experiments. Alternatively, if participants still show chance-level generation performance after an extended test, such a result would strengthen Chun and colleagues' claim that contextual cuing measures truly implicit processes.

4.1.1 Method

4.1.1.1 Participants

Forty-one younger participants (22 women and 19 men) ranging from 18-35 years old (*M* = 22.98, *SD* = 3.23) were recruited from the UCL Psychology subject pool and paid £5 for participating, plus an additional 10 pence for each correct response given in the generation task. None of these participants had taken part in any other contextual cuing experiments.

4.1.1.2 Design

The detection task was a 2 x 24 (Repetition x Block) within-subjects design. Participants' RT for detecting the target and accuracy in identifying the orientation of the target in the configuration were measured in each trial. The variation in the length of the detection task across participants that is intrinsic to the titrated design used subsequently in Experiment 7 does not make analysis of performance by epoch feasible; therefore, blocks of trials were not collapsed into epochs in the remaining experiments to keep the analyses uniform across this chapter. The generation task was a 2 x 4 (Repetition x Block) within-subjects design. Participants' ability to correctly generate the location of the target was measured for each configuration condition in each block.

4.1.1.3 Materials and Apparatus

The detection task used in this experiment was a replication of the 24-block detection task employed by Chun and Jiang (2003), but was implemented by modifying the Visual Basic program used in Experiment 1 to include more blocks of trials. This detection task also differed from the version included in Experiment 1 in that it was followed by an extended generation test (Chun & Jiang, 2003) as in Experiments 3 and 4. Subsequently, the displays shown during the detection task also included 2 dark grey dotted lines to divide the screen into a 4-quadrant matrix in order to match the stimuli used to test awareness in the generation task.

4.1.1.4 Procedure

Except for the omission of the WMS-II test, the procedure was identical to those reported in past experiments. Participants were given the same set of detection task instructions followed by 6 practice trials before beginning the detection task. When the task finished, they answered the series of questions regarding awareness and then completed the generation task. This task lasted approximately 50 min.

4.1.2 Results

4.1.2.1 Detection Task

One participant was excluded from all analyses because of poor accuracy in identifying the orientation of the target letter during the detection task (75%). The remaining participants demonstrated high accuracy overall (*M* = 99%, *SE* = 0.14), with no difference in accuracy between Repeated and Non-Repeated configurations, $t(39) = 0.39$, $p = .70$.

The means of the median RTs for Repeated and Non-Repeated configurations across the experiment are plotted in Figure 4.1. The contextual cuing effect illustrated in Figure 4.1 was reinforced statistically using a repeated measures ANOVA with Repetition (Repeated and Non-Repeated) and Block (1-24) as within-subjects variables. A main effect of Block, $F(23, 897) = 13.36$, $p < .001$, indicated that RTs declined across the blocks. Although the Repetition x Block interaction was not significant, $F(23, 897) = 1.33$, $p > .10$, a significant main effect of Repetition, $F(1, 39) = 12.24$, $p = .001$, confirmed that participants detected targets more rapidly in repeated than Non-Repeated configurations. There was no difference between RTs for Repeated and Non-Repeated configurations in Block 1, $t(39) = 0.74$, $p > .40$. From these results, it can be concluded that substantial and reliable contextual cuing occurred during the detection task.

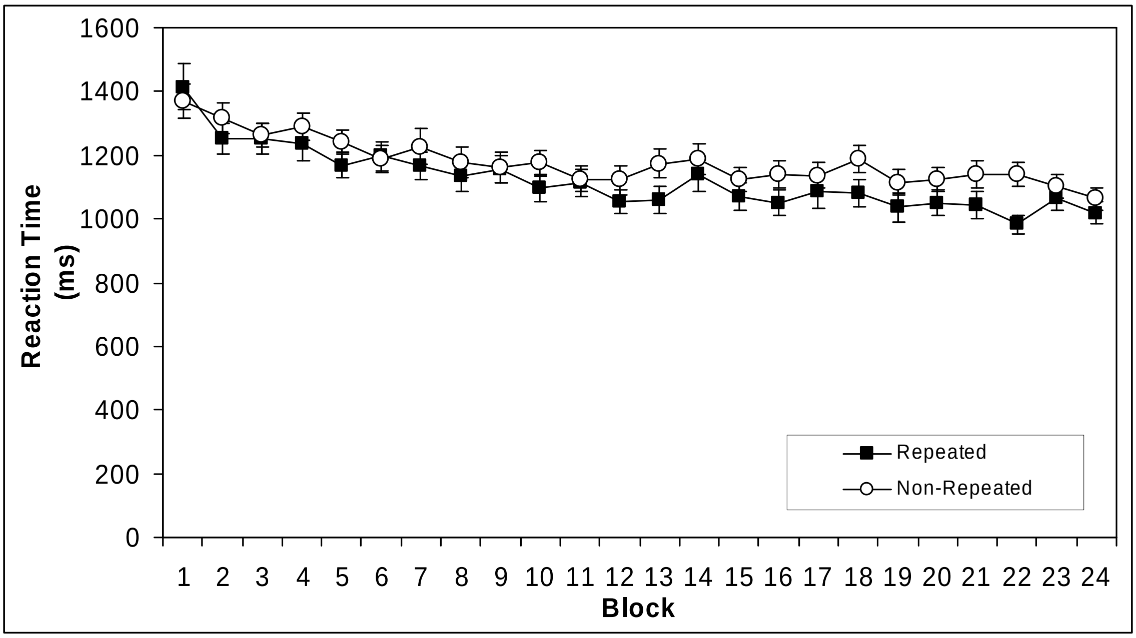


Figure 4.1. **Means of the median reaction time (ms) over 24 blocks of the detection task for Repeated and Non-Repeated configurations in Experiment 5; error bars show standard error of the mean.**

4.1.2.2 Reported Awareness Results

A total of 29 participants (73%) reported awareness for the repetition of configurations, with the mean onset of awareness occurring at Block 10 of the search task. Six (21%) of these aware individuals reported that they adopted a memorization strategy after the repetition became apparent.

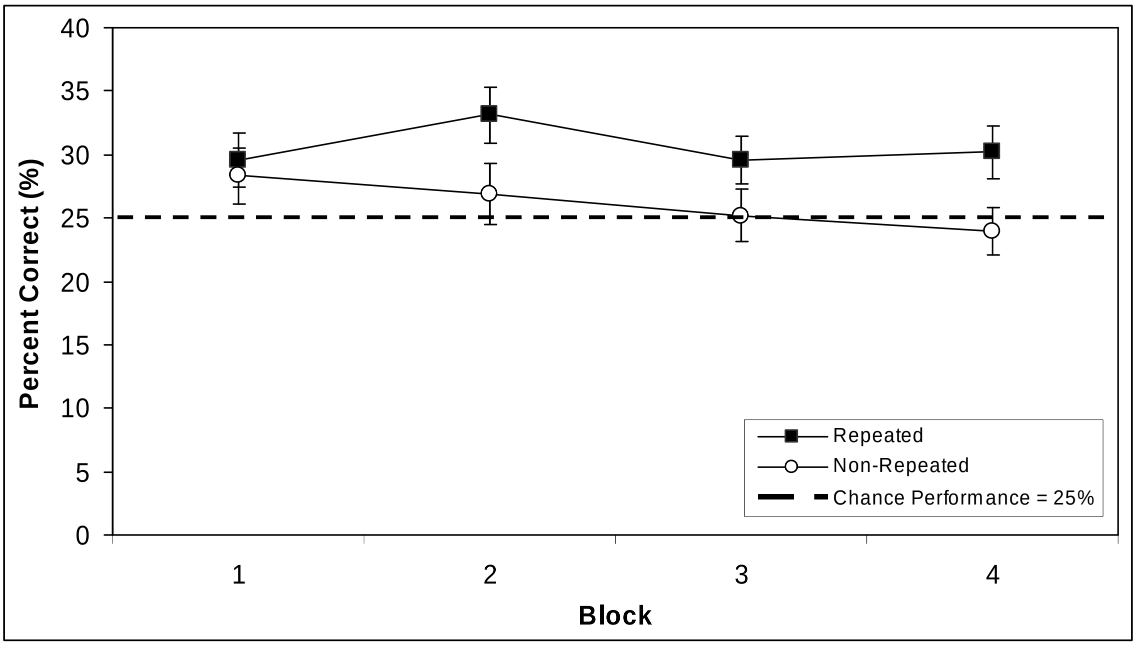


Figure 4.2. **Mean accuracy over the 4 blocks of the generation task for Repeated and Non-Repeated configurations in Experiment 5; error bars show standard error of the mean.**

4.1.2.3 Generation Task

Generation accuracy for each participant was calculated for each configuration type— in each block and overall—then, comparisons were made between configuration conditions in order to evaluate participants' ability to successfully identify the location of the "substitute" L. Chance performance is indicated by no difference in generation accuracy between configuration conditions, because successful generation for Non-Repeated configurations is due entirely to chance. Figure 4.2 plots the mean accuracy scores in each Repetition condition for each block of the task. The overall mean for Repeated configurations was 30.6% and that for Non-Repeated configurations 26.1%. A repeated-measures ANOVA on generation accuracy using Repetition (Repeated or Non-Repeated) and Block (1-4) yielded a significant main effect of Repetition, $F(1, 39) = 8.94$, $p < .006$, confirming higher accuracy for Repeated configurations over Non-Repeated ones across the task. Neither the main effect of Block, $F(3, 117) = 1.19$, $p > .30$, nor the Repetition x Block interaction, $F(3, 117) = 0.65$, $p > .50$, approached significance. One-sample *t*-tests comparing generation accuracy for Repeated and Non-Repeated configurations in all of the blocks of the task to chance performance (25%) showed that generation for Repeated configurations in each block and overall was significantly above chance, all $t(39)$'s > 2.0, all p's < .05, whereas there was no difference between generation for Non-Repeated configurations and chance performance, all $t(39)$'s < 1.58, all p's > .10.

Higher accuracy for Repeated configurations seems to suggest that participants were aware of the repeating contexts in the detection task. However, the small magnitude of this effect raises the concern that successful generation may have occurred for only 1 or 2 of the configurations learned during detection, whereas contextual cuing itself might occur for many more (perhaps all) of the configurations. To address this possibility, we sought to compare the number of Repeated configurations showing contextual cuing during detection to the number of consistently generated Repeated configurations. Since the configurations were different for each participant, this analysis can only be done at the level of individual participants and not aggregated over configurations. An individual analysis for each of the 12 Repeated configurations was conducted for each participant using data from both tasks. The mean RT over the last 4 blocks of the detection task was computed for each Repeated configuration and compared with the participant's mean RT for Non-Repeated configurations over these blocks. A Repeated configuration was classified as learned if this RT fell below the 99% confidence interval of the mean Non-Repeated RT, indicating that contextual cuing occurred (we adopted a 99% interval because the large number [12] of contrasts risks an inflation of the Type I error rate). This analysis yielded a surprising result—namely that the mean number of configurations for which contextual cuing occurred was very low (*M* = 1.55, *SD* = 1.8). Thus, on average, a typical participant only learned 1 or 2 configurations (*Mdn* = 1). For the generation data, overall accuracy was computed for each Repeated configuration. With only 4 presentations of each pattern, it is somewhat arbitrary to determine when a pattern was "learned" in the explicit test. However, if we take 3 out of 4 correct quadrant responses (75%) as indicating awareness, then the number of learned patterns (*M* = 1.55, *SD* = 1.47) is very similar to that obtained in the analysis of the contextual cuing effect. If 4 out of 4 (100%) is the criterion, then the mean number is 0.55 (*SD* = 0 .99).

Figure 4.3 contains plots of each Repeated configuration's RT data against generation performance from high- and low-performing individuals in both tasks. Panel A shows data from the participant with the most configurations showing contextual cuing, panel B from the participant with the fewest configurations showing contextual cuing (this is the participant from among 16 with no reliably learned configurations who showed the smallest search advantage for repeated displays in the last 4 blocks of the task). Panel C is for the participant with the highest overall generation performance, and panel D for the one with the lowest overall generation performance. The figure emphasizes that contextual cuing is not evenly distributed across configurations and small or negative for many. With the mean number of implicitly-learned patterns being so low, it is hard to argue that more information was acquired during the detection task than was accessed in the generation task. But these results tell us nothing about the correlation between contextual cuing and

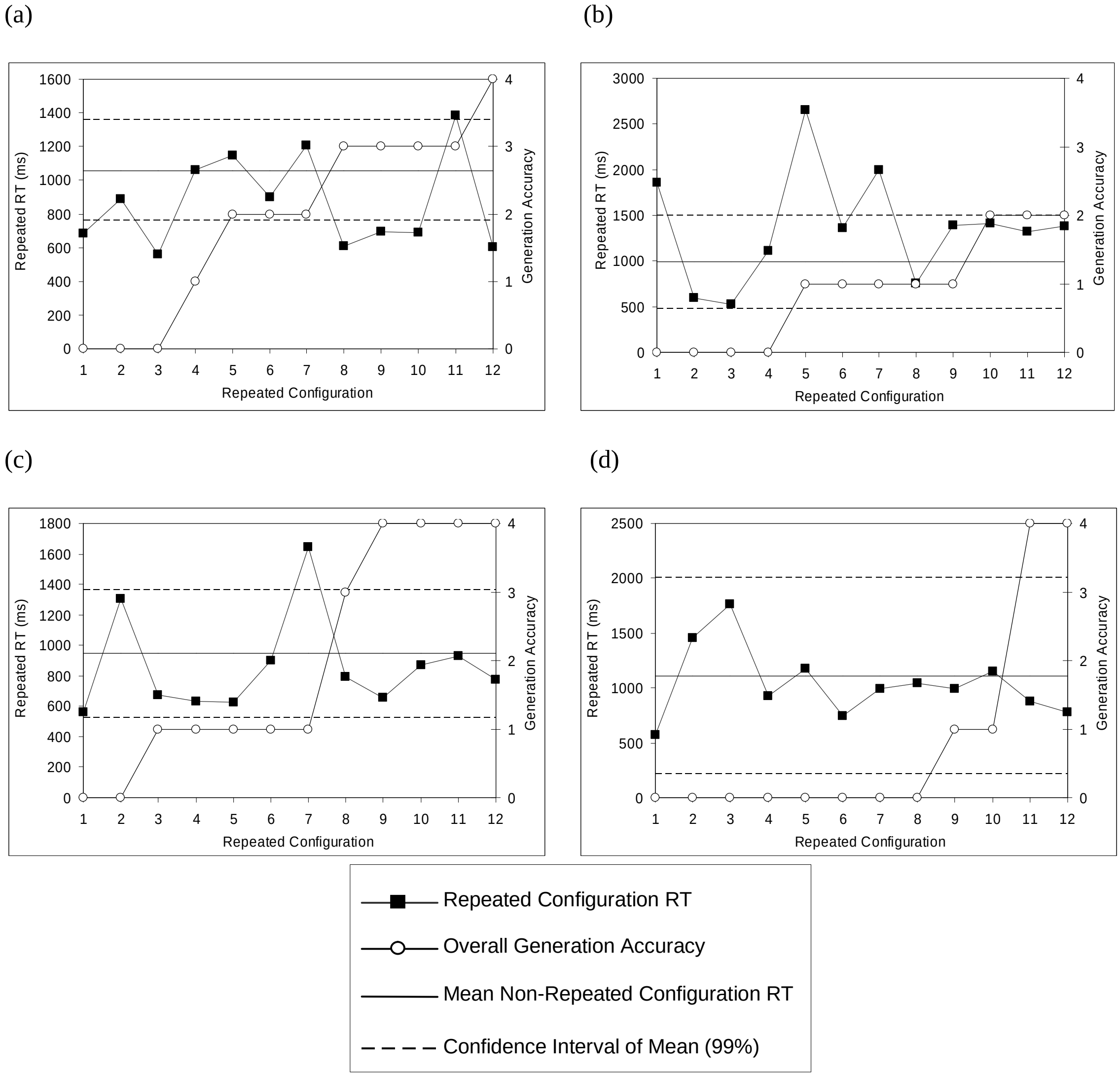


Figure 4.3. **Graphs plotting individual RT data against generation performance for each Repeated configuration (arbitrarily numbered 1-12) from the participant with (a) the most configurations showing contextual cuing, (b) the fewest configurations showing contextual cuing (this is the participant from among 16 with no reliably learned configurations who showed the smallest search advantage for Repeated displays in the last 4 blocks of the task), (c) the highest overall generation performance, and (d) the lowest overall generation performance.**

awareness. We calculated a correlation for each participant between the mean RT of each Repeated configuration over the last 4 blocks of the detection task and percent correct for the same configuration during the generation task. These individual correlations were mostly weak and nonsignificant, and the overall mean correlation (z score transformed) for all of the participants was also low (M = 0.09). However, with a small number of patterns— many of which had generation scores of 50%— the absence of a significant correlation between these measures is perhaps not particularly diagnostic.

In order to explore the implicit-explicit correlation further, participants were divided into 2 groups according to their generation performance. Participants with no overall difference in accuracy between Repeated and Non-Repeated configurations during generation (i.e., across the 48 repeated patterns in the generation test, they made the same number of or fewer correct target quadrant predictions as across the 48 Non-Repeated patterns) were assigned to an Unaware subgroup (n = 17), and their data from the last 4 blocks of the detection task were recalculated. Neither the main effect of Repetition, $F(1, 16) = 3.31$, $p > .09$, nor the Repetition x Block interaction, $F(3, 48) = 1.99$, $p > .12$, were significant. In contrast, an ANOVA using data from the remaining subgroup of aware participants revealed a main effect of Repetition, $F(1, 22) = 10.51$, $p < .004$, though no Repetition x Block interaction, $F(1, 22) = 1.48$, $p > .22$, indicating that successful generation and detection performance were evident in the Aware subgroup, whereas neither contextual cuing nor awareness were present in the Unaware subgroup.

Although this result implies that there is a necessary link between learning and awareness, it does not automatically follow that the information explicitly recalled during the generation task accounts entirely for the contextual cuing shown during the detection task. For example, it is possible that a contextual cuing effect remains after removal of configurations for which participants showed explicit awareness (demonstrated by above-chance generation performance). In order to examine this possibility, RT data for a given configuration were removed from an individual's detection data if the participant showed accuracy greater than chance (25%) for that configuration during the generation task. On average, this criterion resulted in the removal of 4 out of 12 configurations from each participant's dataset. A reanalysis of the detection data showed that there was still a main effect of Repetition, $F(1,39) = 7.53$, $p < .01$, which suggests that the contextual cuing effect was partly sustained by contextual information for configurations that participants were not subsequently aware of during the generation task. We assess the interpretation of such analyses based on post hoc data selection in the Discussion section at the end of the chapter.

Despite the evidence of good generation performance, the results do not contradict the original findings from Chun and Jiang (2003). Performance in Block 1, which is equivalent to the entire 24-trial explicit test used by those authors, also showed no difference in generation accuracy between Repeated (29.6%) and Non-Repeated configurations (28.3%), $t(39) = 0.40$, $p > .60$; however, the fact that higher generation accuracy for Repeated configurations was evident with subsequent blocks of trials suggests that previous experiments did not include enough trials to detect the effect. Increasing the number of trials improved the power of the explicit test to show that participants' awareness of the contextual information from the detection task does produce successful memory for repeated configurations during the generation task.

The data do not allow us to determine whether the null result on Block 1 is simply an issue of low power or whether there is a genuine increase in the Repeated-Non-Repeated effect across blocks (e.g., akin to hypermnesia). The Block x Repetition interaction was not significant, and in any case, the change across blocks seems to be due more to a reduction in performance in the Non-Repeated condition than to an increase in the repeated one. However, this trend was not supported statistically, since the main effect of Block was not significant for generation performance in the Non-Repeated condition, $F(3,117) = 0.88$, $p > .40$.

4.1.2.4 Reliability Analysis

Reliability of the generation task was assessed in a manner similar to the method used in Buchner and Wippich (2000) in which the Repeated trials in each block were divided into 2 subgroups of 6 trials each (using an odd-even method of assignment) for each individual. Then, the mean generation accuracy was computed for each subgroup of trials and, finally, the means of the sub-groups were correlated to evaluate reliability. A high correlation within a set of trials indicates that the task is reliable or, more specifically, that the measure is consistently precise in estimating the participant's awareness of contextual cuing information. Reliability represents the amount of true variance in proportion to observed variance. A measure with low reliability results in data with a higher proportion of error variance, requiring the existing effect to be quite large to reach statistical significance and therefore lowering the statistical power of the measure (Meier & Perrig, 2000).

Reliability in the first block of generation trials was weak and non-significant, $r = 0.09$, $p > .50$, indicating that shorter versions of the generation task used in previous experiments were not reliable. However, when reliability was computed using all 48 Repeated generation trials, a strong correlation was found between the means of the subgroups, $r = 0.46$, $p = .003$, confirming that the inclusion of more trials produces a more reliable test which is statistically more powerful than the single-block design used in Chun and Jiang (2003). Reliability was low in the final generation block, as shown by a weak, non-significant correlation between measures of accuracy, $r = 0.19$, $p > .20$. This result not only confirmed that measuring generation using a single block of trials is not reliable across the experiment, but also discounted the possibility that a change in participant behaviour across blocks was responsible for the awareness effect.

4.1.2.5 Consistency Analysis for the Generation Task

If participants had explicit knowledge about some configurations, then we should be able to observe consistent responding for such patterns in the generation task. We therefore calculated the likelihood of correctly generating the target location to a given configuration, given that all previous responses to that configuration were correct. If responding is consistent, then this likelihood should increase across repetitions (=blocks), since this would mean participants gave the same response to a configuration throughout. The probability of a correct response on Block 1 (first presentation) was 0.30 across all configurations. The probability of a correct response on Block 2—given a correct response on Block 1—was 0.46. On Block 3, the probability of a correct response—given correct responses on the previous 2 presentations—was 0.42. On Block 4, correct responses—conditionalised on correct ones on the previous 3 presentations—occurred with probability 0.79. This pattern of increase suggests that participants adopted consistent response strategies to the patterns they knew. By the fourth presentation, responding was highly accurate (bear in mind that the chance level is 0.25) for patterns that had evoked correct responses earlier.

4.1.3 Discussion

This experiment directly replicated Experiment 1 of Chun and Jiang (2003), with learning observed in the 24-block detection task through a marked facilitation in RT for displays repeated throughout the experiment, and accompanied by no ability to correctly generate the location of the transposed target letter for learned displays during 24 trials of generation. Our assertion that it would be difficult to detect a small, but real, explicit effect using this small number of trials was confirmed by the high generation accuracy that emerged in our extended version of the generation task. When we calculated reliability using a single block of trials in the generation task, we found that an individual block of trials was not reliable on its own. Conversely, when this calculation was based on all 4 blocks of generation trials the measure showed high reliability. Chun and Jiang (2003) found a numerically nonsignificant difference in generation ability between repeated (27%) and Non-Repeated (20%) configurations using a 24-trial task. These authors acknowledged that the null effect may have been due to noisy data; yet, they maintained their claim that contextual cuing was a purely implicit process. When our observations about the reliability of generation from Experiment 5 are applied, it is clear that a more plausible explanation for their lack of effect is the low reliability of the measure rather than their participants' actual lack of awareness. Overall, we argue that the shorter version of this task used in past research may not provide a sound measure of participants' true ability.

Another factor that may contribute to the low reliability of the generation measure employed in past experiments is the lack of inherent strategic direction given to participants in this task. More specifically, the instructions for the generation task do not guide participants to the best way of attaining the vague and seemingly daunting performance goal of identifying the transformed target letter, using information they do not think they possess. In contrast, the detection task imposes rigid response constraints—for example, to search for the target letter as quickly as possible. Consequently, participants may use a variety of response strategies in the generation task. This variation in task approach decreases the consistency of responses given by participants, which could lead to low reliability of the explicit measure (Buchner & Wippich, 2000).

An unexpected result of Experiment 5 was the finding that, on average, the contextual cuing effect for a given participant was borne by only 1 or 2 configurations. Rather than learning about all or most displays, it seems that a small number of displays evoked fast responses. For a typical participant, many repeated configurations were searched as slowly as novel ones.

In Experiment 1, we found that contextual cuing can be accompanied by conscious awareness when the number of recognition trials included in the awareness test was increased. Experiment 5 replicated this finding using a longer generation task, and showed that the block format of this test increased its reliability and sensitivity. However, it is also possible that the performance-based incentive included in Experiments 1 and 5 contributed to the significant awareness effects obtained in these experiments. This would imply that extending the generation task was not the only enhancement to the design of the explicit test.

4.2 Experiment 6

In this experiment, we asked whether the performance-based incentive included in the instructions participants were given before the explicit memory tests in Experiments 1 and 5 might explain why, unlike previous contextual cuing experiments, we obtained an association between learning and awareness. Although analyses of performance in Experiment 5 showed that the block-design of the generation task enhanced the power and reliability of the test to detect awareness, the addition of an incentive for correct responses may have induced a motivational aspect which also enhanced performance.

Shanks and Johnstone (1999) found that participants exhibited high levels of recognition in an SRT experiment, which directly contradicted previous findings of chance-level recognition in a study by Reed and Johnson (1994) using an identical task. Shanks and Johnstone attributed this difference in results to their inclusion of a reward for the highest recognition score for their participants. Perhaps knowing that a reward is attached to correct responses makes participants more inclined to engage in effortful conscious retrieval. In addition, an incentive may also encourage participants to report contextual information, which although accurate, is assigned low confidence or based on a partial representation of a given display.

An additional goal of this experiment was to replicate the awareness effect obtained in the previous experiment using a shorter detection task. Experiment 1 did show that significant recognition ability could coincide with awareness after a 16 block detection task in younger adults. However, as discussed previously, the validity of a recognition test as a measure of awareness in contextual cuing is often questioned on the grounds that performance may be influenced by familiarity judgments or perceptual fluency.

4.2.1 Method

4.2.1.1 Participants

Seventy UCL undergraduates (53 women and 17 men) participated in the experiment. Eight participants were recruited from the UCL Psychology subject pool and given £5 compensation for their participation, while the remaining 62 participants took part in the experiment as part of first-year laboratory class requirement. All participants were between 18 and 23 years old (M = 19.86, SD = 1.29). Participants were assigned at random to the Motivated (n = 21) or the Not Motivated (n = 49) experimental group.

4.2.1.2 Design

The detection task was a 2 x 2 x 16 (Motivation x Repetition x Block) mixed factorial design, with Motivation (Motivated or Not Motivated) manipulated between-subjects, and Repetition (Repeated and Non-Repeated) and Block (1-16) manipulated within-subjects. The generation task was also 2 x 2 x 4 mixed factorial design (Motivation x Repetition x Block).

4.2.1.3 Materials and Apparatus

These were identical to Experiment 5, except that that the length of the detection task was shortened to include only 16 blocks of trials.

4.2.1.4 Procedure

This experiment differed from Experiment 5 only in the wording of the instructions preceding the generation task. Recall that participants in past experiments have been rewarded with 10 pence for each correct response made during the explicit test of awareness. In this experiment, the Motivated group received an extended set of instructions before the generation task, similar to those presented by Shanks and Johnston (1999), informing them that high performance would be rewarded with a £20 book token for the top 5 high scorers. The instructions presented to the Non-Motivated group included no mention of an extra incentive according to performance.

4.2.2 Results

4.2.2.1 Detection Task

As expected, participants demonstrated high overall response accuracy for detecting the orientation of the target during the task (M = 98%, SE = 0.2). An ANOVA on participants' response accuracy by Repetition (Repeated vs. Non-Repeated) and motivation group (Motivated or Not Motivated) also showed that there were no differences in response accuracy between motivation groups (Motivated, M = 98%, SE = 0.4; Not Motivated, M = 98%, SE = 0.2), $F(1, 68) = 0.63$, $p > .25$. Response accuracy for Repeated and Non-Repeated configurations was also similar within each group and between groups, F's < 0.06, p's > .81.

The ANOVA on detection task performance showed a reliable main effect of Block, $F(15, 1020) = 23.46$, $p < .001$, which is evidence that acclimation to the task led to faster responding overall. A main effect of Repetition, $F(1, 68) = 18.77$, $p < .001$, and a Repetition x Block interaction, $F(15, 1020) = 2.33$, $p < .003$, also emerged from the analysis, indicating that greater response efficiency developed for Repeated trials in relation to Non-Repeated trials. There were no significant effects of or interactions with Motivation, all F's < 2.74, all p's > .10, but of course the procedures for these groups did not differ at this stage of the experiment.

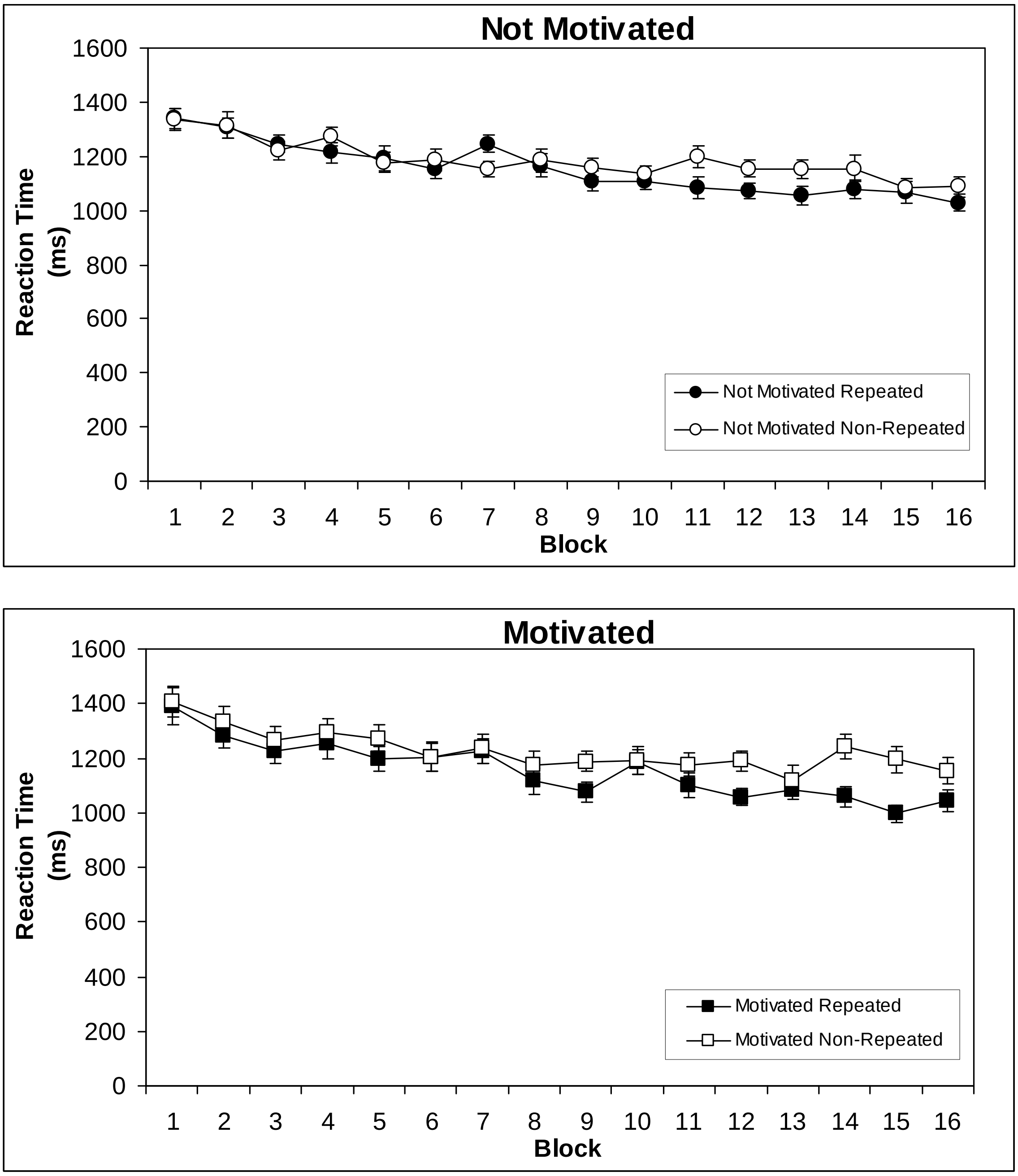


Figure 4.4. **Median RTs (ms) over the 16 blocks of the detection task for Repeated and Non-Repeated configurations of Not Motivated participants (top panel) and Motivated participants (bottom panel); error bars show standard error of the mean.**

In Figure 4.4, there appears to be a difference in the magnitude of the contextual cuing effect in the Motivated and Not Motivated groups by the end of the task. A repeated-measures ANOVA of detection performance in the last 4 blocks of the task still showed an overall main effect of Repetition, $F(1, 68) = 26.78$, $p < .001$, and Block, $F(3, 204) = 2.88$, $p < .04$. The Repetition x Motivation interaction was marginally significant, $F(1, 68) = 3.16$, $p = .08$, reflective of the development of a somewhat greater contextual cuing effect in the Motivated group (Motivated, $M = 131$ ms, $SE = 28$; Not Motivated, $M = 64$ ms, $SE = 21$).

4.2.2.2 Generation Task

Each motivation group's performance in the generation task is presented in Figure 4.5, and analysed using a repeated-measures ANOVA with Repetition (Repeated vs. Non-Repeated) and Block (1-4) as within-subjects variables and Motivation (Motivated or Not Motivated) as a between-subjects variable. Surprisingly, this analysis showed that conscious awareness was not present in these participants, since neither the main effect of Repetition, $F < 1$, nor the Repetition x Block interaction approached significance, $F(3, 204) = 1.47$, $p > .20$. The Repetition x Block x Motivation interaction was marginal, $F(3, 204) = 2.33$, $p = .08$, but there were no other indications that the Motivation manipulation enhanced performance, all other F's < 1.46, p's > .22.

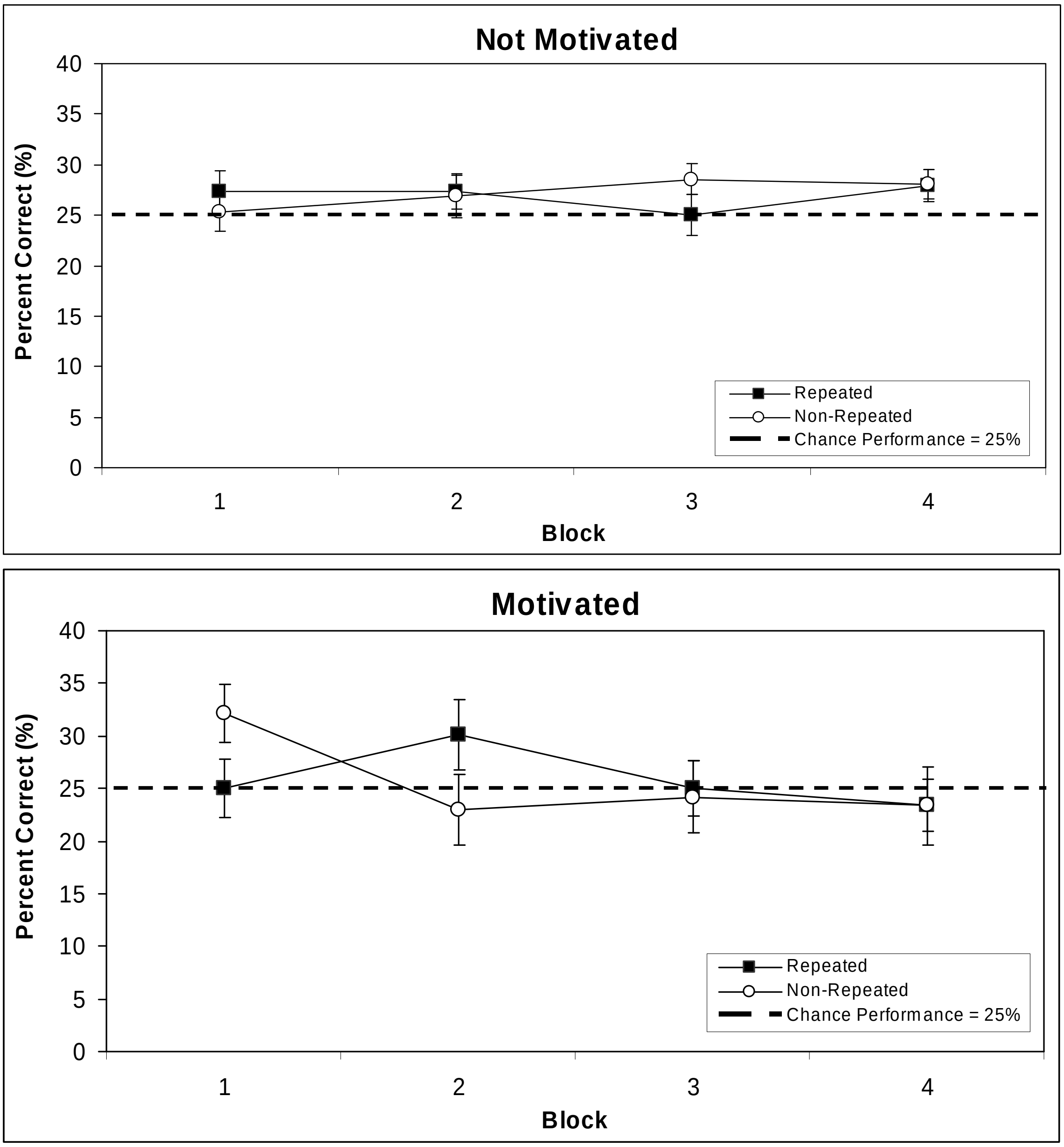


Figure 4.5. **Mean generation accuracy over the 4 blocks of the generation task for Repeated and Non-Repeated configurations in the Not Motivated (top panel) and Motivated (bottom panel) groups; error bars reflect standard error of the mean.**

Post-hoc pairwise comparisons of generation accuracy between Repeated and Non-Repeated configurations were non-significant for both motivation groups, all t's < 1.72, *p*'s > .10. Generation accuracy for Repeated configurations was numerically higher than chance level (25%) in the Not Motivated group for the majority of the test, but these results were only marginally significant in one-sampled comparisons of overall performance and accuracy in Block 4 to chance, $t(48) = 1.92$, $p = .06$; $t(48) = 1.96$, $p = .06$, respectively; all other *t*'s < 1.28, *p*'s > .20. None of the one-sampled comparisons of generation accuracy for Repeated configurations to chance approached significance in the Motivated group, all *t*'s < 1.53, *p*'s > .14.

All of the results from analyses thus far have failed to replicate the awareness effect obtained using a generation test in younger participants in Experiment 5. To quantify learning and awareness further and to draw comparisons to Experiment 5, we looked at detection and generation performance for each configuration on an individual participant basis using the procedures described in that experiment. We expected the number of configurations driving the contextual cuing effect to be lower in this experiment, since participants received fewer blocks of detection trials (16 versus 24 blocks in Experiment 5). However, these analyses of individual data showed that contextual cuing occurred for slightly more configurations on average for participants in this experiment than in Experiment 5 ($M = 1.87$, $SD = 1.84$).

There were also no differences in the number of learned configurations between participant groups (Motivated, $M = 1.80$, $SD = 1.85$; Not Motivated, $M = 2.05$, $SD = 1.85$), $t(68)= 0.52$, $p > .60$. However, awareness for Repeated configurations only occurred for about 1 configuration on average ($Mdn = 1$), when the criterion was determined by 75% accuracy to a given Repeated configuration, with motivational instruction having no effect on the number of configurations participants generated correctly (Motivated, M = 1.05, SD = 1.32; Not Motivated, M = 1.16; SD = 1.01), $t(68) = 0.40$, $p > .60$.

Participants in the Not Motivated group showed a higher number of contextually cued Repeated configurations than the number they showed conscious awareness of, $t(48) = 2.23$, $p < .03$. This trend was also apparent in the Motivated group, but was only marginally significant, $t(20) = 1.99$, $p = .06$.

4.2.2.3 Reported Awareness Results

Sixteen Motivated (76%) and 37 Not Motivated participants (76%) reported noticing the repetition of configurations, $\chi^2 = 0.004$, $p > .94$, on average by Block 7 of the task, $t(51) = 0.09$, $p > .93$. Only 4 Motivated and 3 Not Motivated participants relied upon a memorization strategy after becoming aware of the repetitions. Nevertheless, as consistently shown in past experiments, there were no significant interactions with reported awareness when it was entered as a factor in an ANOVA of detection performance, all F's< 1, or generation performance, all F's < 1.85, p's > 14.

4.2.3 Discussion

This study investigated the effects of motivation on conscious awareness of contextual cuing information during the generation task. Even though the motivated individuals showed slightly higher levels of contextual cuing, they still demonstrated a lack of awareness during the generation task just like participants who did not receive instructions concerning a performance-based incentive. Therefore, we can conclude that the inclusion of a reward in Experiment 5 was not the source of younger participants' demonstration of awareness.

The presence of above-chance levels of generation ability in Experiment 5 after a 24-block detection task versus the lack of a generation effect shown in the present experiment when a 16-block detection task was used, implicates the length of the detection task as a factor in obtaining participant awareness. Despite their lack of awareness using a shorter detection task, the individual analysis indicated that participants in this experiment showed contextual cuing for a greater number of configurations than in Experiment 5.

4.3 Experiment 7

If a unitary system of memory provides the best framework for understanding contextual cuing, target location information should be readily available to conscious retrieval mechanisms at the same point at which a contextual cuing effect is first observed. In this experiment, we will attempt to examine conscious access to contextual cuing knowledge in its earliest stages of behavioural expression. Traditionally in contextual cuing experiments, the explicit test is given after a uniform number of blocks of detection trials. Such a design does not allow us to determine whether the onset of contextual cuing and awareness truly coincide, it only informs us of whether participants are able to consciously access information after substantial levels of learning have occurred.

A further concern with a uniform length detection task is that administration of the awareness test does not take account of individual differences in participants' development of contextual cuing. Imposing a rigid detection task length is inherently problematic, because it assumes that all participants will acquire contextual information at a similar rate. Hence the awareness test may be measuring participants at different stages in learning. If we could quantify contextual cuing so that it is uniform across participants we may be able to examine awareness against a consistent level of learning.

In this experiment, the length of the detection task was tailored for each participant according to the point at which contextual cuing first occurred, and then a generation test was administered. If unconsciously acquired contextual cuing knowledge is exclusive to a distinct implicit memory store, as proposed by the dual-systems theory, then the onset of a learning effect in participants may not be accompanied by the ability to support conscious retrieval as revealed in a generation task.

4.3.1 Method

4.3.1.1 Participants

Twenty-five University College London (UCL) undergraduates (15 women and 10 men) participated in the experiment. All participants were between the ages of 18 and 35 years old (*M* = 22.92, *SD* = 4.06), and naïve to the purpose of the experiment. All participants received a baseline fee of £3 and 10 pence for each correct response during the generation task.

4.3.1.2 Design

The number of trials a participant received in the detection task varied individually according to the onset of contextual cuing, but all participants' data included at least 4 blocks of detection trials (3 initial exposure blocks before the presence of contextual cuing was tested, and a final block of trials after contextual cuing was shown). The awareness test used in this task was a generation task identical in design to the versions used in Experiments 3-6.

4.3.1.3 Materials and Apparatus

The program used to present and create stimuli in this experiment was based on the program from Experiment 6 but modified to present a titrated version of the detection task.

4.3.1.4 Procedure

This experiment used methods identical to the previous experiments, except that the duration of the detection task was contingent upon each participant’s performance. Commencing after the third block, a paired-samples t-test was computed to compare the RTs of Repeated and Non-Repeated configurations at the end of each block of trials. If a participant’s target detection in a given block was statistically faster for Repeated configurations than for Non-Repeated configurations, it was inferred that contextual cuing had occurred. These pairwise comparisons were assessed at the conservative $p < .01$ level as a precaution against ending the task without a learning effect. An accuracy criterion of 20/24 correct responses was imposed to ensure contextual cuing was not contaminated by inaccurate search performance. After expressing significant learning, participants received 1 more block of trials before the progression to the generation task. All participants received at least 5 blocks, but no more than 16 blocks of detection trials.

4.3.2 Results

Five participants received all 16 blocks of trials, and did not show significant contextual cuing when the difference between RTs for Repeated and Non-Repeated configurations was averaged in their last 2 blocks of data. The aim of this experiment was to see if information learned implicitly during the detection task was also accompanied by explicit memory, hence the analyses only included the 20 participants who exhibited evidence of contextual cuing by their last 2 blocks of the detection task.

4.3.2.1 Detection Task

All participants demonstrated high accuracy overall (M = 99%, SE = 0.21) with no difference in accuracy between responses for Repeated and Non-Repeated configurations, $t(19) = 0.85$, $p > .40$. Participants received an average of 10 (SD = 4.41) blocks of trials, excluding the follow-up block, before meeting the fixed learning criterion.

A repeated-measures ANOVA with Repetition (Repeated and Non-Repeated) and Block (1-4) as within-subjects variables was performed using RTs from each participant's last 4 blocks of target detection trials. Only the last 4 blocks of trials were included in the ANOVA, since the number of blocks differed between participants and all participants performed at least 4 blocks of trials. The Block effect was not significant over the last 4 blocks of the task, $F < 1$. There was a significant main effect of Repetition, $F(1, 19) = 108.99$, $p < .001$, and a Repetition x Block interaction, $F(3, 57) = 7.30$, $p < .001$, demonstrating that participants exhibited a reliable contextual cuing effect by the end of the detection task.

Notice, in Figure 4.6, that a reduction in contextual cuing is apparent during the last block of the task. This smaller cuing effect follows a block with statistically substantial cuing, $t(19) = 8.57$, $p < .001$, and is most likely a result of regression toward the mean rather than an exhibition of less learning by participants.

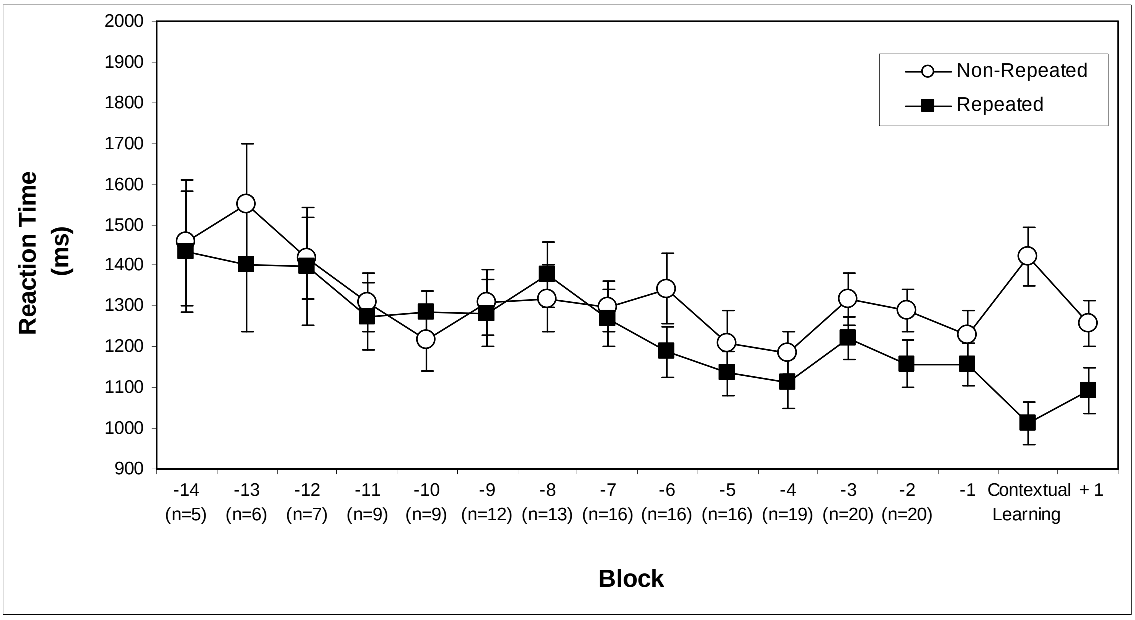


***Figure 4.6.* Means of the median RTs for Repeated and Non-Repeated Configurations in the titrated detection task ranging from number of blocks preceding contextual cuing to 1 block after the onset of contextual cuing; error bars show standard error of the mean.**

4.3.2.2 Generation Task

A repeated-measures ANOVA on generation performance showed no evidence that participants were consciously aware of information from the titrated detection task, since neither of the main effects of Repetition or Block, nor the Repetition x Block interaction approached significance, all *F*'s < 1.53, *p*'s > .20. As shown in Figure 4.7, generation accuracy in the Repeated condition numerically exceeded chance level in Block 3 of the task, but not significantly, $t(19) = 1.37$, $p > .18$. Pairwise comparisons were also not reliable, $t(19) = 1.38$, $p > .18$, and evidence of this trend was not sustained into Block 4.

To assess awareness and learning for individual Repeated configurations within participants, we used the same procedure described in the 2 previous experiments.

Contextual cuing was determined using RTs from Repeated configurations in each participant's last 4 blocks of detection trials and compared to a 99% confidence interval of the mean of the Non-Repeated RTs from these last 4 blocks of the detection task. A criterion of over 75% generation accuracy over the generation task was taken to signify awareness. The titrated design allows us to examine performance at the onset of contextual cuing.

Despite a lack of an overall difference in generation ability for Repeated and Non-Repeated configurations, participants still showed evidence of reliable conscious retrieval for 1 configuration on average (*Mdn* = 1), meaning that the number of configurations generated in this experiment was similar to that of Experiment 5 where a reliable awareness effect was present. More compellingly, on average participants showed contextual cuing for more Repeated configurations (*Mdn* = 6) than any of our previous experiments, which implies that the magnitude of the contextual cuing effect may be strongest in the earliest stages of learning during the detection task. Direct comparisons confirmed that the number of contextually cued configurations exceeded the number of generated configurations (Detection, $M = 5.55$, $SD = 1.43$; Generation, $M = 0.95$, $SD = 1.15$), $t(19) = 10.51$, $p < .001$.

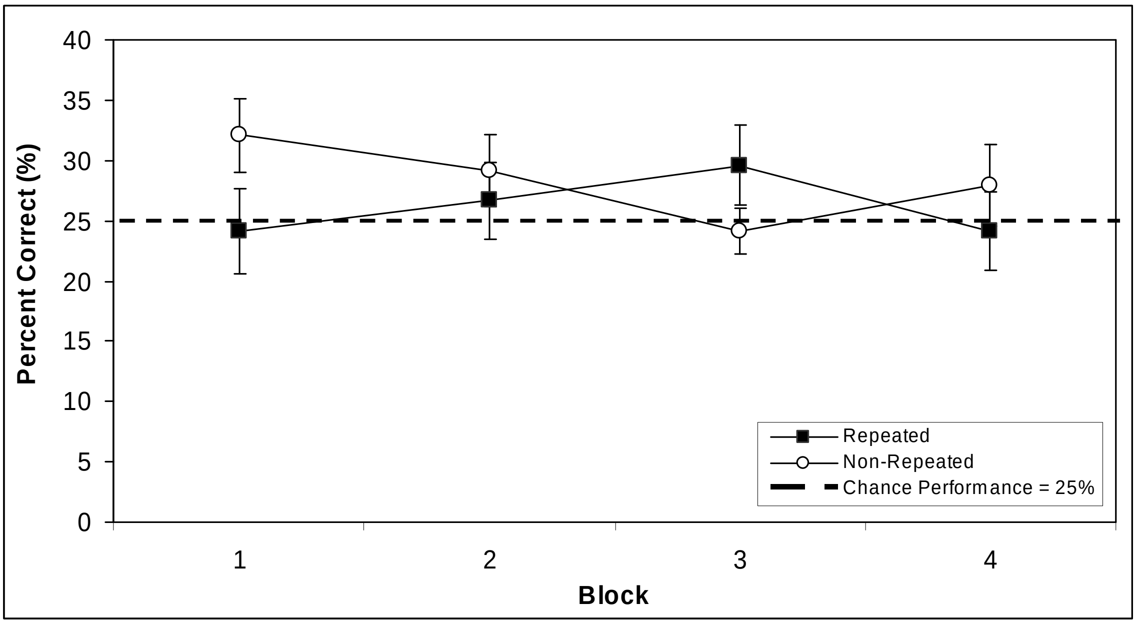


Figure 4.7. **Mean accuracy over 4 blocks of the generation task for Repeated and Non-Repeated configurations administered after participants demonstrated a contextual cuing effect during the detection task in Experiment 7; error bars show standard error of the mean.**

4.3.2.3 Reported Awareness

Twelve participants (60%) reported becoming aware of the pattern of configurations during the experiment, and only 1 of these participants reported adopting a memorization strategy after the repetitions became apparent. It is unlikely that contextual cuing was affected by awareness, as the reported block of awareness (M = 6.3, SD = 2.45), and the block of the experiment in which significant contextual cuing was shown, (M = 10.4, SE = 1.07), did not overlap. Further similarity in learning was shown when the repeated-measures ANOVA for the target detection task was re-analysed using Awareness as a between-subjects variable, as all interactions with Awareness were nonsignificant, all F's < 1. Additionally, the length of the target detection task did not differ by reported awareness, $t(18) = 0.12$, $p > .90$. Generation performance, in a re-analysis with Awareness included as a between-subjects variable, mirrored previous results in showing no significant interactions between the other variables and Awareness, all F's < 1.51, all p's > .20. From these analyses it is reasonable to conclude that performance on both tasks was unaffected by participants' discovery of the repetition of configurations in the experiment.

4.3.3 Discussion

The aim of this experiment was to ask whether conscious awareness of target location could occur at the first manifestation of learning. Whereas participants in previous experiments received the same number of trials during the detection task, in this experiment participants were given the explicit test at the onset of learning. The majority of individuals demonstrated contextual cuing within 16 blocks of trials; however, evidence of conscious awareness was not present at the onset of learning.

The results of this experiment suggest that there may be a point at which knowledge may be accessible only via unconscious facilitation mechanisms, and therefore not immediately available to conscious processing, as a dual-systems perspective of memory would suggest. However, it is still possible that when learning and awareness are measured simultaneously, these abilities can coincide (unconscious acquisition and conscious retrieval) within the same task.

4.4 Experiment 8

While Experiments 1 and 5 showed that contextual cuing knowledge is accessible to both implicit and explicit memory in younger adults, Experiments 6 and 7 found that only implicit memory resulted when participants were given a shorter or titrated learning task. In

Experiment 8, we attempted to resolve this contradiction by asking whether implicit and explicit accessibility are synchronous when tested concurrently.

Younger adults in Experiment 1 also exhibited significant recognition ability, whereas in Experiment 6, generation ability did not exceed chance even though participants in these experiments received identical amounts of detection training. These results underscore the differences between the generation and recognition tasks. Consequently, both tests were included in the present experiment.

4.4.1 Method

4.4.1.1 Participants

Eighty participants (49 women and 31 men) were randomly assigned to the recognition or generation test condition (*n* = 40 per group). All participants were between the ages of 18 and 30 years old (*M* = 21.81, *SD* = 3.14), and naïve to the purpose of the experiment. Roughly half of the participants were unpaid and took part for course credit, whereas the remaining participants (*n* = 19, Generation; *n* = 14, Recognition) received a baseline fee of £4 and an additional 10 pence for each correct response on explicit test trials.

4.4.1.2 Design

All participants received an altered version of the detection task from Experiment 5, which was a 2 x 16 (Repetition x Block) within-subjects design. The type of explicit task was manipulated between-subjects. The Generation condition showed only Repeated configurations using a 4-block repeated measures design and measured accuracy in generating the target location on each trial, whereas the Recognition condition used the 2 x 2 (Repetition x Block) within-subjects design of the recognition test used in Experiment 1.

4.4.1.3 Materials and Apparatus

The instructions and procedure described in Experiment 5 were also used for creating and presenting all of the configurations of letters used for this experiment; however, in order to concurrently measure implicit and explicit memory for the learned contextual information, the detection and generation— or detection and recognition— tasks were combined into a single procedure. In this new task, generation or recognition trials were presented intermixed with detection trials within an experimental block. In order to accommodate the new concurrent presentation format, the version of the generation task used in Experiments 3, 4, 5 and 6 was altered. Generation trials only contained Repeated configurations in order to preserve the 4-block design used previously, and also because presenting Non-Repeated configurations as generation trials may interfere with the expression of contextual cuing. The shorter 16 block detection task used previously was also adopted in this experiment.

In the Generation group, there were 12 blocks of 28 concurrent trials (24 detection and 4 generation). These 12 blocks of concurrent detection and generation trials were also preceded by 3 blocks of just detection trials, since it would not have been useful to measure generation performance before learning had occurred. The 16th and final experimental block was also made up solely of detection trials in order to see if contextual cuing performance changed in the absence of concurrent explicit assessment.

In 3 blocks of concurrent detection and generation trials, the 12 generation trials cycled through the entire set of repeated configurations. Thus, each individual Repeated configuration was shown 4 times across the 12 concurrent blocks as generation trials. The 4 generation trials in each block contained a Repeated configuration with a target location from each quadrant of the screen so that random guessing within each block—and not just across the task overall—would yield chance performance.

The experiment also included a Recognition group in which the generation trials were substituted for a recognition task, used previously by Chun and Jiang (1998) and in Experiment 1, to assess explicit memory. Participants were asked to discriminate between Repeated configurations and Non-Repeated ones not presented previously during the experiment. This version included 12 blocks of 24 detection trials and 4 recognition trials presented concurrently, and like the Generation condition, these were preceded by 3 blocks and followed by 1 block of pure detection trials. Two Repeated and 2 Non-Repeated configurations were shown during the 4 recognition trials, so that over the 48 total trials each Repeated configuration was shown twice. The Repeated configurations were the same as those in the detection task, while a new set of 24 Non-Repeated configurations was created for the recognition portion of the task. These new "Recognition Non-Repeated configurations" were also generated using the procedures used to create those used on detection trials.

4.4.1.4 Design

This new task with concurrent detection and generation/recognition trials began identically to Experiment 5, with instructions to locate the letter T as quickly as possible within the configuration of letter L's, followed by 6 practice trials. After receiving 3 blocks of 24 target detection trials, participants viewed another set of instructions introducing the explicit test. In order to prevent response delays from inducing changes in finger positions (since response requirements changed between trial types), the response keys for the detection task were moved to the numeric keypad, with participants using the left and right arrows on the “4” and “6” keys.

Participants in the Generation condition were told that in addition to seeing trials requiring them to quickly locate the T in the display, the rest of the experiment would also include some other trials (on which they would not be timed) with displays composed entirely of Ls. They were informed that they had seen all of these displays previously during the experiment, but now an L had been placed where a T would have occurred. Their task was to try to guess which quadrant of the screen contained the “substitute” L, and respond using the numeric keypad with the response layout mimicking the spatial layout of the quadrants in the display, with the “7” and “9” keys corresponding to the top left and right quadrants and the “1” and “3” keys corresponding to the bottom left and right quadrants. These trials were preceded by a different orientation screen to alert participants of the type of response required on the next trial. Prior to detection trials, participants were shown a blank grey screen with a white dot in the centre for 1 sec to direct their attention to the middle of the screen (as in all previous experiments reported), whereas the screen shown before generation trials was a black screen with a centred white dot and a red question mark in each quadrant of the display.

In the Recognition group, participants were also told that they would be shown additional trials, but these configurations would appear similar to those seen during detection trials (11 Ls and 1 T). However, on these trials, they were told that they could take their time and decide whether or not they had seen that configuration previously during the experiment. The “7” key on the numeric keypad signalled that they had seen the display, or it was an “old” configuration, while the “9” key signalled they thought the configuration was “new”. Participants were alerted to the type of trial to be shown—just as in the generation condition—by the orientation screen.

Auditory feedback was still given on detection trials, but participants did not receive performance feedback on generation or recognition trials. Participants also received a break between blocks of at least 10 sec as in Experiment 5. After all 16 blocks of trials, participants were informed of their performance on the explicit task. The new combined task took about 1 hr to complete in both explicit test conditions.

4.4.2 Results

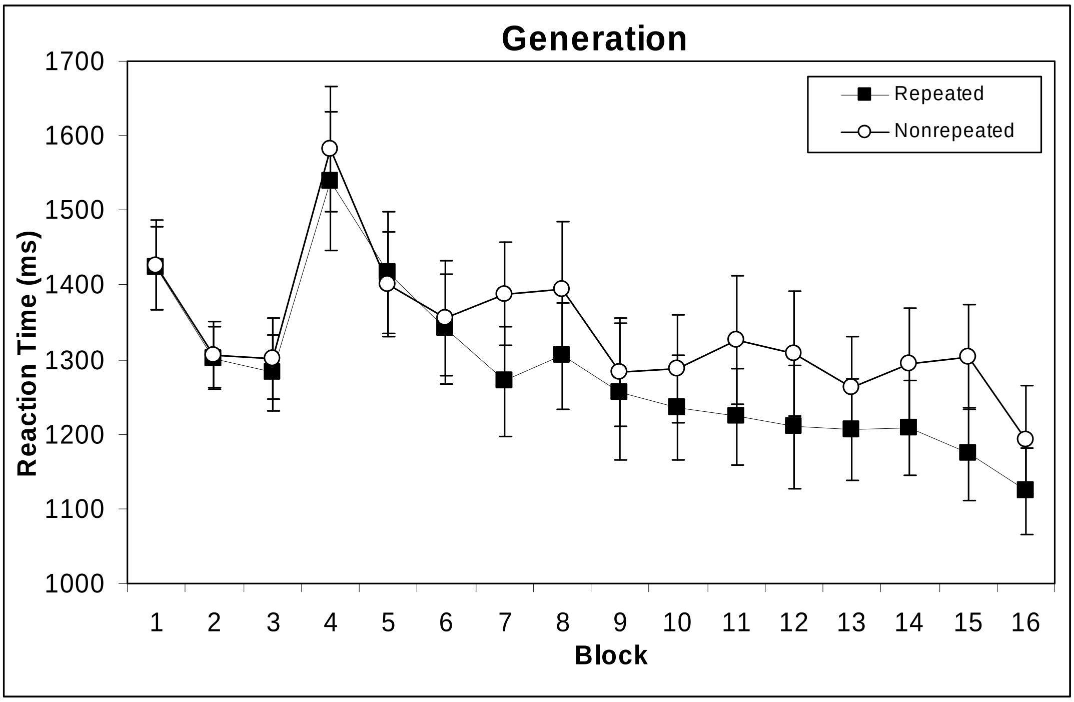
4.4.2.1 Detection Task

Participants in both explicit test conditions demonstrated high accuracy overall in responding to the orientation of the T in the display (Generation, M = 97%, SE = 0.30; Recognition, M = 99%, SE = 0.14); however, participants in the Recognition condition systematically responded correctly more often, $F(1, 78) = 15.68$, $p < .001$. There were no differences in response accuracy between Repeated and Non-Repeated displays overall or within each explicit test condition, F’s < 0.18, p’s > .67, (Generation, Repeated, M = 97%, SE =0.23 ; Non-Repeated, M = 97%, SE = 0.27; Recognition, Repeated, M = 99%, SE = 0.13 ; Non-Repeated, M = 99%, SE = 0.13)

Figure 4.8 shows the results of the detection task for participants in the Generation and Recognition conditions. Slower detection performance in both Configuration conditions was shown in Block 4, which coincides with the introduction of the concurrent presentation of explicit trials in the task. A mixed ANOVA was performed on all of the data with Repetition (Repeated vs. Non-Repeated) and Block (1-16) as within-subjects variables and Explicit Test (Generation vs. Recognition) as a between-subjects variable.

The results using a shortened detection task replicated performance in previous experiments, with significant main effects of Repetition, $F(1, 78) = 22.05$, $p < .001$, and Block, $F(15, 1170) = 10.58$, $p < .001$, and a non-significant Repetition x Block interaction, $F(15, 1170) = 1.13$, $p > .30$. The significant main effect of Repetition is evidence that contextual cuing occurred, since RTs for Repeated and Non-Repeated configurations were not different in Block 1 for participants in either explicit test condition, Generation, $t(39) = 0.09$, $p > .90$; Recognition, $t(39) = 1.46$, $p > .15$. There were no significant interactions of Repetition or Block with the explicit test variable, all F's < 0.87, all p's $> .60$; therefore, it can be concluded that equivalent contextual cuing developed in the Generation and Recognition groups.

The dual-task requirement participants faced when asked to respond to both detection and generation or recognition trials may have caused contextual cuing in detection trials to be diminished. Greater cuing in Block 16—when only detection trials were presented—would support this idea of the concurrent design of this experiment suppressing the expression of cuing. Accordingly, cuing performance in blocks with and without explicit test trials were compared by taking the difference in RTs between Repeated and Non-Repeated configurations in Block 15—when detection trials were included with generation or recognition trials—and comparing it to the difference in RTs for configurations when just detection trials were shown in Block 16. There was no difference in the amount of cuing demonstrated by participants between blocks in either explicit test condition, Generation, $t(39) = 1.32$, $p > .19$; Recognition, $t(39) = 0.39$, $p > .60$, so the concurrent presentation of the explicit trials alongside detection trials did not appear to interfere with the contextual cuing effect.



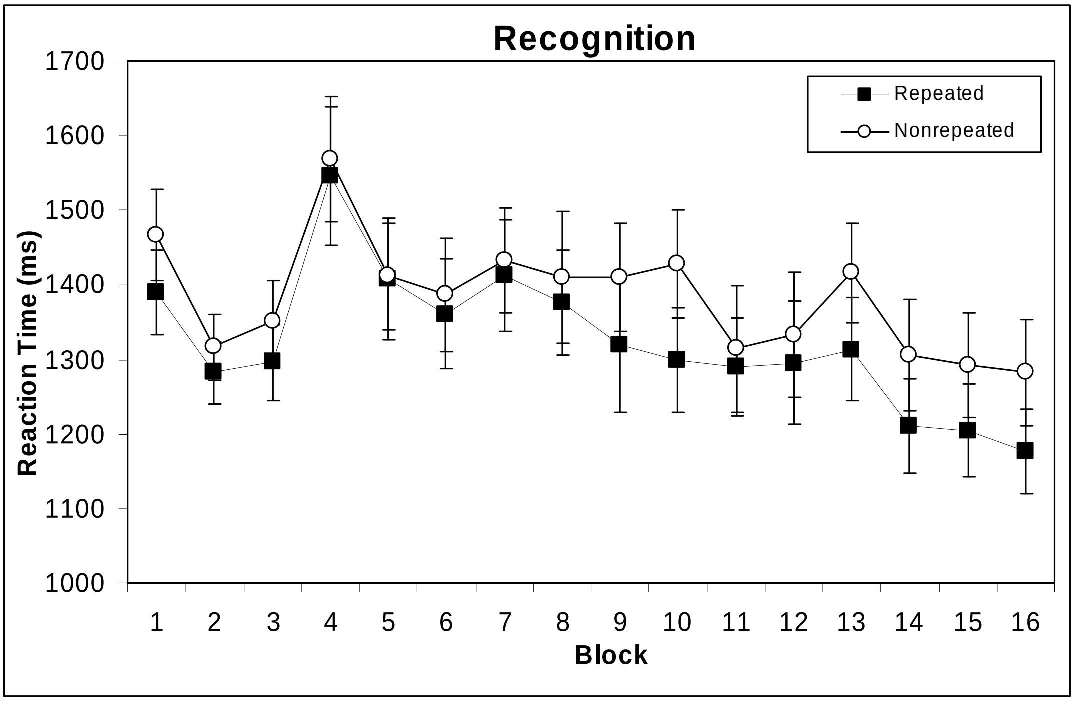


Figure 4.8. **Detection performance over 16 blocks for participants in the Generation (n = 40) and Recognition (n = 40) conditions in Experiment 8. Individual points reflect means of the median reaction time (ms); error bars show standard error of the mean.**

4.4.2.2 Generation Task

Generation was solely measured for Repeated configurations, so accuracy could only be compared to chance performance. Accuracy averaged across all 12 blocks was significantly higher than chance (M = 29%, SE = 1.5), $t(39) = 2.57$, $p = .01$. In order to examine generation performance at different points during the task, accuracy was calculated after each cycle of 12 generation trials presented across 3 blocks of concurrent trials, which was equivalent to performance on 1 block of trials for Repeated configurations from the generation task in Experiments 1, 5, and 6. A repeated-measures ANOVA was performed using Generation Block (1-4) as a within-subjects variable and revealed no effect for Generation Block on generation performance, $F(3, 117) = 0.90$, $p > .40$—which as illustrated by Figure 4.7 shows that above-chance generation performance was sustained throughout the task.

Interestingly, generation performance rose above chance as early as the first cycle of trials (M = 30%, SE = 2.3), $t(39) = 2.33$, $p < .03$; however, as shown in Figure 4.9 this seems to occur before contextual cuing itself was evident. A repeated-measures ANOVA was performed on the detection trials corresponding to the presentation of this first cycle of generation trials in Blocks 4-6 and showed a non-significant main effect of Repetition, $F(1, 39) = 0.27$, $p > .60$, a significant main effect of Block, $F(2, 78) = 9.89$, $p < .001$, and a non-significant Repetition x Block interaction, $F(2, 78) = 0.43$, $p > .60$, confirming that generation ability preceded contextual cuing.

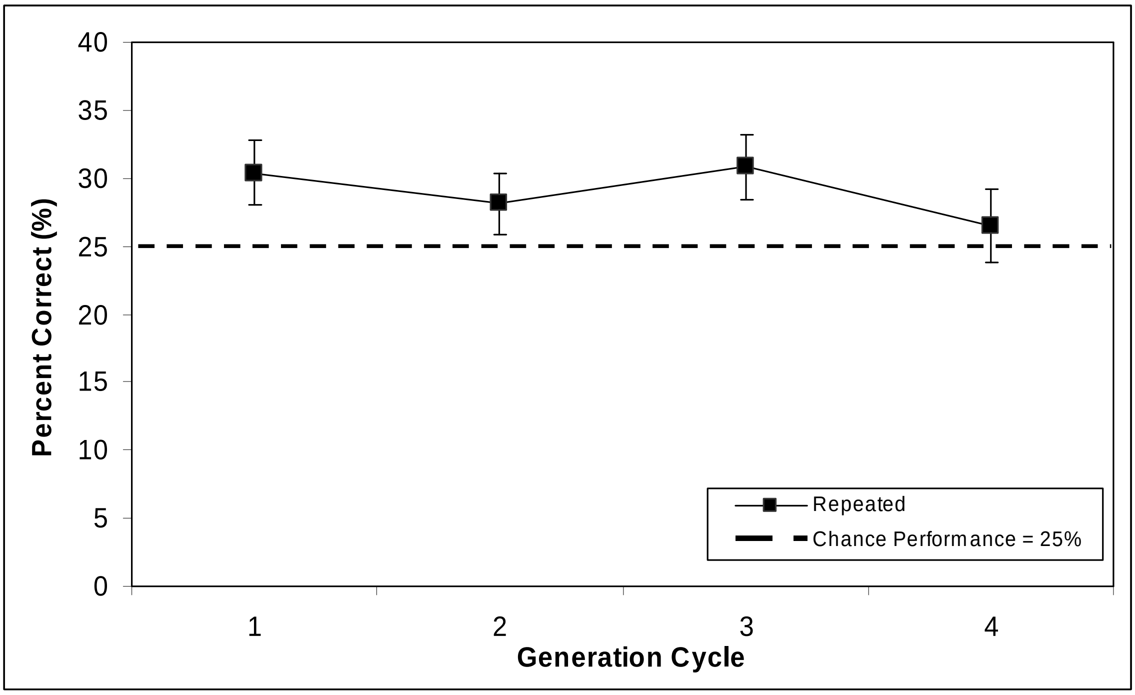


Figure 4.9. **Mean generation accuracy across cycles of generation trials in Experiment 8. One cycle is the point at which 12 generation trials are shown, or all Repeated configurations have been displayed; error bars show standard error of the mean.**

As with all previous experiments in this chapter, the number of Repeated configurations showing contextual cuing was calculated for each participant, focusing on data from the final 4 blocks. This analysis showed that, on average, contextual cuing occurred for only 1 of the 12 Repeated configurations (M = 0.98, SD = 1.53). Across all generation trials, when 3 of 4 correct quadrant responses (75%) were taken as an indicator of awareness for an individual configuration, participants were aware of roughly the same number of configurations (M = 0.98, SD = 1.05). However, there was a decrease in the number of configurations learned overall in the concurrent task compared to Experiment 5, which is most likely related to the shorter task duration used in this experiment.

Correlations for each participant's mean RT for each Repeated configuration over the last 4 blocks of the detection task and percent correct for the same configuration across all generation trials showed a weak and non-significant relationship both at the individual level, and overall, $r = 0.02$.

Finally, we divided participants into 2 groups according to their level of explicit performance and then re-analysed their implicit performance. Participants with response accuracy at or below chance level for Repeated configurations in the last cycle of generation trials (i.e., across the last 12 generation trials in blocks 13-15 of the experiment) were assigned to a no-awareness subgroup ($n = 26$), and their data from the last 4 blocks of the detection task were re-calculated. Unlike Experiment 5, the main effect of Repetition was highly significant, $F(1, 25) = 13.15$, $p < .001$. A comparable analysis using data from the remaining sub-group of aware participants also revealed a (marginally) significant main effect of Repetition, $F(1, 13) = 4.17$, $p > .06$. The difference between the groups was not significant. We address the interpretation of this finding in more detail in the Discussion. (Note that, because of the small number of awareness test trials in each block, there is insufficient data to ask whether contextual cuing was reliable just for those configurations showing chance-level explicit knowledge).

4.4.2.3 Recognition Task

Recognition ability was measured by calculating the hit and false-alarm rates for responses to Repeated configurations from Non-Repeated configurations across recognition trials. The hit rate ($M = 0.50$, $SE = 0.03$) was significantly higher than the false-alarm rate ($M = 0.41$, $SE = 0.03$) across all 48 trials of the concurrent task, $t(39) = 3.68$, $p < .001$. In order to see whether performance changed with the presentation of more detection trials, the hit and false-alarm rates were also calculated after each cycle (equivalent to 6 blocks of the concurrent trials), in which all 12 Repeated trials had been shown as recognition trials, and the data are shown in Figure 4.10. After the first repetition, the hit rate (M = 0.42, SE = 0.03) was not significantly higher than the rate of false-alarms (M = 0.41, SE = 0.03), $t(39) = 0.40$, $p > .60$. Yet, by the second repetition, discrimination ability was evident with a rise in hits (M = .58, SE = .03) versus false-alarms (M = 0.41, SE = 0.03), $t(39) = 5.13$, $p < .001$.

The null result in the first cycle of recognition trials suggests that contextual cuing may have occurred without awareness. In order to investigate this, a repeated-measures ANOVA was performed on the corresponding detection trials in Blocks 4-9, and it showed a non-significant main effect of Repetition, $F(1, 39) = 2.26$, $p > .10$, a significant main effect of Block, $F(5, 195) = 3.31$, $p < .008$, and a non-significant Repetition x Block interaction, $F(5, 195) = 0.42$, $p > .80$. Therefore, neither contextual cuing nor recognition ability were present during the first half of the task.

An individual analysis of learning was performed to calculate the number of configurations learned in detection and recognition. Participants showed contextual cuing across Blocks 13-16 for approximately 1 Repeated configuration (M = 1.23, SD = 1.46), which is similar to the amount learned in the generation task and in Experiment 5. For recognition, each pattern was presented only twice across the entire experiment, so our classification took a pattern as learned if the correct response was made on both trials. On this basis, the number of configurations learned for recognition was M = 3.5, SD = 1.93, although this should, of course, be interpreted with caution due to the small number of observations per pattern. As before, the correlation between the mean RT to a Repeated configuration during the last 4 blocks of the experiment and the number of correct recognition responses for the same configuration was calculated for each participant. These correlations tended to be non-significant and their *z*-transformed mean was small ($M = 0.09$).

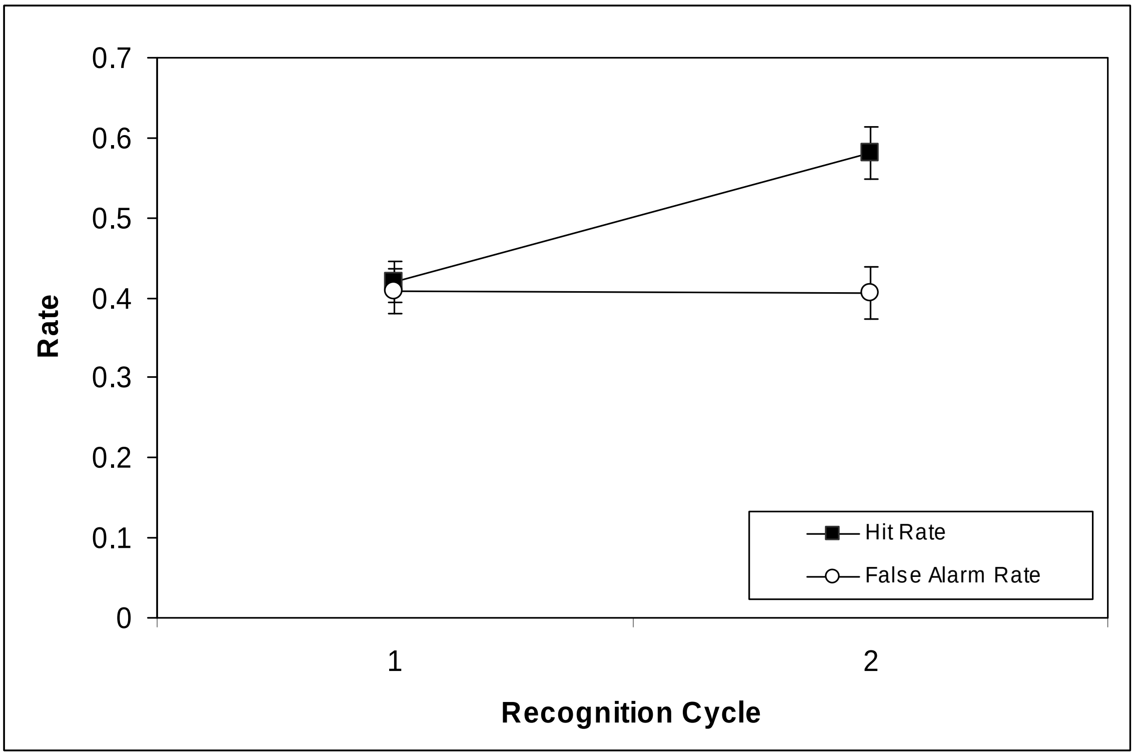


Figure 4.10. **Hits and false alarms segmented by cycles of recognition trials in Experiment 8. One cycle is equivalent to 24 recognition trials, comprising all 12 Repeated and 12 Non-Repeated configurations; error bars show standard error of the mean.**

Participants with no difference in recognition accuracy between Repeated and Non-Repeated configurations in the last cycle of recognition trials (i.e., a negative or zero difference in hit and false-alarm rates across the last 12 Repeated and 12 Non-Repeated patterns shown over Blocks 10-15 of the experiment) were assigned to a no-awareness subgroup (n = 12), and their data from the detection task in Blocks 10-16 were re-calculated. The main effect of Repetition, $F(1, 11) = 5.06$, $p < .05$, achieved significance. A corresponding analysis on aware participants also revealed a main effect of Repetition, $F(1, 27) = 8.96$, $p < .006$, meaning that contextual cuing was present regardless of reported awareness.

4.4.3 Discussion

In sum, contextual cuing emerged after approximately 10 blocks of trials. Participants had explicit knowledge of target location as indexed by generation and recognition tests. Above-chance generation preceded contextual cuing (being significant across the first 3 blocks) whereas recognition did not. Thus (1) at a group level, there is no evidence of implicit contextual cuing preceding explicit awareness, and (2) generation seems to be more sensitive than recognition. On the other hand, “unaware” participants did show contextual cuing (addressed in the Overall Discussion).

4.5 Discussion of Experiments 5-8

The majority of contextual cuing experiments find that participants show facilitation for displays they have been exposed to repeatedly during a visual search task (but see Lleras & Von Muhlenen, 2004), which indicates that participants acquire some sort of mental representation of these displays that they rely upon to aid their search. However, the same individuals do not show evidence of being able to consciously use these representations to support performance during a recognition or generation test. This dissociation between unconscious learning and conscious retrieval has led researchers to conclude that the contextual cuing phenomenon illustrates the existence of a purely implicit processing mechanism. This chapter was concerned with examining whether the failure to experimentally show conscious access to contextual cuing knowledge in previous experiments was a true effect, or if it was a result of inadequate power and reliability in the methods the previous studies used.

The first experiment presented in this chapter directly replicated Experiment 1 of Chun and Jiang (2003), with learning observed in the 24-block detection task through a marked facilitation in RT for displays repeated throughout the experiment, and accompanied by no ability to correctly generate the location of the transposed target letter for learned displays after 24 trials of generation. In addition, our assertion that it would be difficult to detect a small, but real, explicit effect using this small number of trials was confirmed by the high generation accuracy that emerged in our extended version of the generation task. When we calculated reliability using a single block of trials in the generation task, we found that an individual block of trials was not reliable on its own. Conversely, when this calculation was based on all 4 blocks of generation trials the measure showed high reliability. Chun and Jiang (2003) found a numerically nonsignificant difference in generation ability between Repeated (27%) and Non-Repeated (20%) configurations using a 24-trial task. These authors acknowledged that the null effect may have been due to noisy data; yet, they maintained their claim that contextual cuing was a purely implicit process. When our observations about the reliability of generation from Experiment 5 are applied, it is clear that a more plausible explanation for their lack of effect is the low reliability of the measure rather than their participants' actual lack of awareness.

Overall, we argue that the shorter version of this task used in past research may not provide a sound measure of participants' true ability.

A factor that may contribute to the low reliability of the generation measure is the lack of inherent strategic direction given to participants in this task. More specifically, the instructions for the generation task do not guide participants to the best way of attaining the vague and seemingly daunting performance goal of identifying the transformed target letter, using information they do not think they possess. In contrast, the detection task imposes rigid response constraints—for example, to search for the target letter as quickly as possible. Consequently, participants may use a variety of response strategies in the generation task. This variation in task approach decreases the consistency of responses given by participants, which could lead to low reliability of the explicit measure (Buchner & Wippich, 2000).

An unexpected result of Experiment 5 was the finding that, on average, the contextual cuing effect for a given participant was borne by only 1 or 2 configurations. Rather than learning about all or most displays, it seems that a small number of displays evoked fast responses. For a typical participant, many repeated configurations were searched as slowly as novel ones.

In Experiment 6, contextual cuing still emerged when a shorter 16-block detection task was used, though generation ability did not exceed chance. Despite having less exposure to predictive configurations and thus less opportunity to gather information during the detection task, the learning effect still appeared to be based on 1 or 2 configurations. Evidence of conscious awareness was not obtained in this experiment, even though a more reliable and powerful blocked-design generation task was employed.

Recall that Experiment 1 included the same abbreviated detection task, but significant recognition ability accompanied contextual cuing in younger participants. Experiment 6's findings of null awareness when a generation task is used highlights the differences between these explicit tests and, further, suggests that only generation ability is affected by the reduction in task duration. Moreover, the fact that a shorter implicit task adversely affects participants' performance on the generation test implies that unconscious processes may have preferential access to the informational trace formed in contextual cuing.

Experiment 7 allowed us to examine whether contextual cuing and conscious awareness resulted when the generation task was administered at the first indication that contextual cuing was present during the detection task. In doing so, the titrated design of the task also enabled us to take into account individual differences in the amount of exposure necessary for acquiring contextual cuing. The majority of participants showed reliable contextual cuing in fewer than 16 blocks of detection trials, but showed no indication that this contextual cuing information was consciously accessible. Generation ability did not exceed chance, yet the number of configurations in which participants demonstrated consistently accurate responses was similar to previous experiments where an awareness result was obtained.

It was also surprising that the learning effect in Experiment 7 was composed of faster responses to about half of the Repeated configurations on average, which was a larger number than was demonstrated during the generation task. Analyses of Experiments 5 and 6, where longer detection tasks were used, showed that the learning effect was made up of detection facilitation for markedly fewer configurations. Presumably, the initial memory trace of all of these configurations is of low strength at the onset of contextual cuing. Perhaps there is a great deal of fluctuation in the amount of information participants are able to retain throughout the detection task, so as the quality of the initial representation of certain configurations increases over the duration of the detection task there is greater competition for continued storage in memory. However, search facilitation would continue to develop for the select few configurations that were sustained successfully into higher quality representations in memory and continued to support the contextual cuing effect that results by the end of the task. The instability of contextual cuing knowledge is also demonstrated in the noisiness of the learning effect from block to block that is shown traditionally in the detection task.

In light of these results, proponents of a dual-systems account of memory might rationalize the awareness effect obtained in Experiments 1 and 5 as an indication that contextual cuing in these experiments was supported by a memory source that can only be operated on using conscious processes. Experimenters holding this view assume any informational representations yielded when an awareness effect is present are definitively neither implicit, nor a true demonstration of contextual cuing. Consequently, these experimenters also often adopt a practice of discounting data from participants showing awareness (subjective or objective) on these grounds (Howard et al., 2004).

This binary interpretation of learning and memory can be challenged not only because the argument is circular (since it assumes that the detection task is inherently process pure) but also because it is clear that participants showing an awareness effect were not especially subjectively aware or deliberate in their approach to performing the detection task to indicate reliance on a purely explicit strategy. Although subjective measures of awareness are often poor gauges of actual conscious knowledge (Dienes, Broadbent, & Berry, 1991; Shanks & Johnstone, 1998; Willingham, Greeley, & Bardone, 1993), they do allow us to infer something about what participants gathered about their own intentionality in performing the task. Reported awareness during the series of questions before the explicit task was similar across experiments regardless of participants' awareness on the explicit tests, and (except in one of the experiments) reported awareness was not a factor affecting contextual cuing performance.

In Experiment 8 we asked whether participants' awareness coincided with their implicit processing by presenting trials from both the explicit and implicit tasks concurrently. Although Experiments 5 and 6 showed evidence of learning without awareness, the online measure of awareness in Experiment 8 provides a more sensitive test as it allowed for concurrent assessment. Participants were both able to respond faster to repeated configurations on detection trials and successfully recognize or accurately generate the target location of altered repeated configurations during the new concurrent task; therefore, it seems that conscious availability of these contextual representations revealed on generation or recognition trials coincides with the "unconscious" demonstration of contextual cuing during detection trials.

Experiment 8 also addressed the difference in sensitivity for contextual cuing information between the 2 explicit tasks used in contextual cuing experiments. The first experiment using this paradigm by Chun and Jiang (1998) included a recognition task in which discrimination judgments are made on the basis of the participant's sense of familiarity of the displays. Some have argued that in order to conclude that the information supporting contextual cuing is not available to awareness, the test of explicit memory must try to engage the same source driving efficient visual search during the detection task (i.e., cuing of locations by the distracter context). It is not obvious that recognition judgments, based on display familiarity, achieve this. Chun and Jiang (2003) addressed this limitation by introducing the generation task which requires participants to search the display for the missing target letter and then to respond to its location, hence closely matching the demands of the detection task and thus in principle making it more sensitive to contextual cuing knowledge. This speculation was confirmed in Experiments 5 and 8. Participants in the generation group showed awareness earlier than those in the recognition group in Experiment 8, whereas participants in the generation conditions of Experiment 5 showed a roughly equal number of learned individual configurations between the detection and generation tasks.

A somewhat surprising result was obtained with the concurrent measurement test design. The generation group showed awareness of contextual knowledge before the contextual cuing effect was evident on detection trials, meaning that awareness seems to have preceded the expression of learning during visual search. Parenthetically, the same outcome has been found in the SRT task (Perruchet, Bigand, & Benoit-Gonin, 1997; Shanks & Johnstone, 1999). Some would argue that the dual-task requirement may have interfered with the expression of contextual cuing knowledge. We doubt that this is a viable explanation, since detection performance did not improve when only detection trials were presented during the last block of the experiment. We believe that the generation effect emerges before contextual cuing because the explicit test is intrinsically more sensitive than the implicit test. In Experiment 5, a reliable contextual cuing effect was not demonstrated until Block 12 of the detection task, whereas in Experiment 8, a significant overall generation effect was shown after 4 blocks of trials.

Additionally, we address the issue of selecting participants or configurations post hoc on the basis of their explicit knowledge and examining performance on the associated implicit test. Numerous studies have analysed performance in this way by computing the implicit task performance only of participants scoring at or below chance on an explicit measure, or only for trials on which explicit performance was at chance. Here, analyses of contextual cuing in samples of “unaware” participants in both conditions of Experiment 8 (though not of those in all previous experiments) showed reliable learning effects. Likewise, configurations in Experiment 5 which were associated with chance-level generation also showed reliable learning effects. But we argue that these findings still do not constitute clear evidence of implicit learning. The reason is that such results are also predicted by single-system models which do not recognize the implicit-explicit distinction (Shanks & Perruchet, 2002; Shanks, Wilkinson, & Channon, 2003) and which assume that awareness is a necessary concomitant of learning. Suppose that there is a single knowledge base which controls performance both in an implicit test, such as contextual cuing, and in an explicit test, such as generation. Suppose also, however, that independent sources of noise or error contribute to each performance measure. Under such circumstances, it will inevitably be the case that simulated participants selected after the fact as scoring at or below chance on the explicit measure will score above chance on the implicit measure (Perruchet & Amorim, 1992), and likewise for configurations selected post hoc on the same basis. Indeed these models can even predict correlations of zero between implicit and explicit measures despite them arising from the same underlying representation (Berry, Henson, & Shanks, 2006; Kinder & Shanks, 2003). We believe that, for this statistical reason, this form of analysis rarely supports the inferences that are drawn from it.

Note that we are not arguing for a causal role of awareness in learning. Such a conclusion would not be warranted on the basis of our findings. An alternative possibility is that learning and awareness are both consequences of a common underlying cause such as a particular type of mental representation (Lovibond & Shanks, 2002), yielding the slightly weaker conclusion that awareness is a necessary condition for learning.

This research underlines the importance of evaluating the empirical reliability of cognitive measures in these types of experiments. When attempting to demonstrate dissociations between measures of processing, adequate consideration must be given to ensure that both tests have enough power to statistically obtain the effect in question, and caution must be exercised in assuming that the same information is being measured between the tasks. The experiments in this chapter show that previous dissociations between learning and awareness in contextual cuing may have emerged because of an insensitive test of awareness which clearly calls for a revised interpretation of the contextual cuing phenomenon.

In conclusion, the results observed in this chapter suggest that an explanation based on independent implicit and explicit systems is not necessary to account for contextual cuing. Therefore, the lack of contextual cuing ability in older adults in the two previous chapters may be symptomatic of general loss of memory function associated with cognitive ageing, rather than reflective of impairment to a specific implicit system.

5 How Does Cognitive Ageing Affect Contextual Cuing?

The purpose of this thesis was to evaluate the effects of cognitive ageing in implicit learning and memory using a contextual cuing task. Performance on implicit tasks have been promoted as invulnerable to age-related cognitive decline, in contrast to performance on explicit tasks where older adults exhibit known impairments. This idea is heavily entrenched in theories of memory which assume completely separate implicit and explicit systems whose operating mechanisms are supported by different areas of the brain. This final chapter summarizes key findings of the experiments reported in the previous chapters, and addresses possible reasons why conclusions from previously published research may differ in many respects to our own. It will be argued that implicit processing is not immune to the effects of cognitive ageing. Possible explanations for these age-related impairments will be discussed in light of the empirical evidence put forth in this thesis and existing theories of learning and memory.

5.1 Contextual Cuing is Not Age Invariant

Experiment 1 in Chapter 2 compared implicit learning in a contextual cuing task in healthy older adults to younger adults, and found that older adults did not learn as well as younger adults during the detection task. This finding conflicts with Howard et al.'s (2004) conclusion that performance in the contextual cuing task is age invariant.

The basis of Howard et al.'s (2004) claim, as discussed in Chapter 2, was the lack of an interaction with age and the other indicators of contextual cuing in an overall ANOVA of the data. In Experiment 1 we sought to avoid this practice of relying on a single result, let alone a null result, and analysed a variety of behavioural measures before coming to a conclusion. The statistical interaction between age and contextual cuing, that was not present in Howard et al., did emerge in the overall ANOVA of data in our Experiment 1. An analysis of the presence of cuing within each epoch also showed that younger adults sustained a significant contextual cuing effect continuously throughout the last half of the detection task, while older adults did not show an effect at any point in the task. Furthermore, when the amount of contextual cuing was quantified using a proportional learning measure the older adults' mean cuing score was not only significantly lower than the younger adults', but also was not even greater than zero.

It is important to mention that these age-related performance differences resulted when performance was compared after only 16 blocks of detection trials, whereas Howard et al.'s (2004) original study employed 30 blocks of trials. This inconsistency in results implies that the number of trials during the detection task seems to be tied to the strength of the memory for a given configuration. Yet when older adults in our Experiment 3 received a direct replication of Howard et al.'s 30-block detection task, they still failed to show statistical evidence of a contextual cuing effect. As with the individual experiments, a combined analysis of the 70 older participants tested in Experiments 1, 3, and 4 (compared with 36 in Howard et al.'s Experiment 1) yields a nonsignificant final-epoch contextual cuing effect of 26 msec [$t(69) = 0.72$, $p > .47$; exactly the same number (35) of individuals showed a positive cuing effect (i.e., Repeated faster than Non-Repeated) as showed a negative cuing effect]. Across all younger participants in our experiments in Chapters 2 and 3, the cuing effect (M = 107 msec) is highly reliable [$t(187) = 4.85$, $p < .001$; a positive cuing effect was shown by 127 of these and a negative effect by 60, with one showing an effect of 0 msec]. On this point, our results are in less sharp disagreement with those of Howard et al. (2004). As discussed previously, a numerical trend for weaker contextual cuing in older compared to younger participants was clear in their data.

Two other studies have reported the occurrence of contextual cuing in healthy older adults of a similar age range to those tested in this thesis when they were included as a control group in examinations of contextual cuing in other settings (Negash, et al., 2007; Peterson et al., 2002). In this respect, proposing that age-related impairments occur in contextual cuing might be viewed as an outlier in relation to the existing literature; but upon further investigation of the conclusions drawn by the aforementioned studies it is evident that they do not actually contradict the findings presented in this thesis.

Peterson et al. (2002) compared a group of older individuals (n = 12) to a younger group using a contextual cuing task after a 60-block detection task to examine the changes to attentional guidance with age, and found no age effects to suggest performance differences. Peterson et al. (2002) also based their conclusion, like Howard et al. (2004), entirely on null interactions with age in an ANOVA of detection performance, but their small sample size is likely to have lowered the power of their analysis in detecting a between-groups performance difference. Moreover, the older group's data were never presented alone to confirm that a contextual cuing effect would still be obtained in an individual ANOVA, and the supposed presence of contextual cuing in older adults occurred only after an extraordinarily high number of detection trials. More compellingly, younger and older adults in Peterson et al. (2002) also showed similar degrees of recognition on an awareness test. This provides a possible explanation for their results, since it is common for younger adults to perform much better than older adults on measures of explicit memory. It is possible that the older adults relied upon conscious processing to show a contextual cuing effect during the detection task, but it is more plausible that the ANOVA of the recognition was also not powerful enough to show a difference in recognition performance. Given the concerns outlined above, the evidence provided in Peterson et al. (2002) that contextual cuing occurs normally in an older population is questionable, and can most likely be attributed to the low power of their study.

Negash et al. (2007) looked at genetic contributors to the development of Mild Cognitive Impairment (MCI) by comparing two groups of healthy older adults who differed only in that one group was composed entirely of carriers of a gene called Apolipoprotein (ApoE) that is thought to be a predictor of development of MCI. Older participants who were non-ApoE carriers did show contextual cuing, while older ApoE carriers and MCI patients did not develop this ability, which led Negash et al. (2007) to propose that the contextual cuing task could prove to be a useful tool in predicting later onset of MCI after further longitudinal examination. The occurrence of learning in older non-ApoE carriers is at variance with the results included in this thesis, but since a younger control group was not included in this study it is not possible to determine if age was also a factor in contextual cuing performance. That being said, Negash et al. also suggested that cognitive ageing produces marked performance difficulties on this task in healthy older adults, albeit of a certain genetic make-up; therefore, there is no reason to view these findings as in disagreement with our own.

There was considerable evidence from the experiments presented in Chapters 2 and 3 to establish that cognitive ageing negatively influences contextual cuing in otherwise healthy older adults. This conclusion stands contrary to other studies reported in the contextual cuing literature (Howard et al. 2004; Peterson et al. 2002). This variance in results draws attention to the fact that previous studies' claims that contextual cuing is age invariant depended entirely on null age effects in one analysis, and thereby underscores the importance of thoroughly examining data for possible underlying performance differences.

5.2 Contextual Cuing and Processing Speed

In addition to showing little evidence of contextual cuing, older adults were also consistently slower than younger adults in Experiment 1. While it has been suggested that poor performance on cognitive tasks in older adults may be explained by a general slowing that develops with age (Salthouse, 1985; 1996), the results reported in Chapter 3 suggest that older adults' slower response speeds cannot account for their poor contextual cuing ability.

The logic of the design of Experiments 2 and 3 was that if processing speed is a factor contributing to performance in the contextual cuing task, then slowing down responses in younger adults should produce learning deficits that are similar to those demonstrated by older adults in Experiment 1. Manipulating the offset of the distracter letter stimuli and the contrast ratio of the display was viewed as more complex than simply slowing down the pace of the task for younger adults in Chapter 3. The intention of these manipulations was to attempt to simulate the actual processing lag that older adults experience. Yet despite younger adults' slower response latencies after viewing a low display contrast or offset distracter letters, there was no evidence from Experiments 2 and 3 to suggest that younger adults' contextual cuing performance was as poor as older participants' when they were slower to respond. When younger adults received tailored manipulations of the distracter letters to customise target-distracter similarity in Experiment

3, it did negatively affect learning, but only in relation to other younger participants from Experiment 1 who did not receive task adjustments to alter their response latencies. Correspondingly, when older adults' responding was made faster by altering the letter stimuli in Experiment 4, to simulate the response latencies of younger adults, it did not lead to the attenuation of their contextual cuing impairments.

Traditionally, examinations of processing speed also attempt to establish a statistical link between measures of cognitive functioning and standardized measures of processing speed. According to Processing Speed Theory, a positive relationship between these variables is expected with advancing age. Correlational analyses between processing speed and proportional cuing were performed for Experiments 3 and 4; however, neither experiment showed a relationship of this nature between processing speed and contextual cuing in older adults or younger adults. The only sign of a correlation occurred in the group of younger adults who were given a tailored offset manipulation to slow down their response latencies in Experiment 3, but, contrary to what is predicted by Processing Speed Theory, this correlation was negative and only marginally significant.

Howard et al. (2007) adopted an empirical approach similar to Experiments 2 and 3 in their investigation of the contributions of processing speed to age-related differences in sequence learning. By degrading the screen-contrast ratio and increasing the response-to-stimulus intervals, Howard et al. (2007) were able to slow down responding in younger adults in an SRT task. Similar to the findings of Experiment 3, younger adults' speed impediments in Howard et al. (2007) impaired sequence learning performance in relation to younger controls—though not older adults. Interestingly, the low contrast condition included was found to impair only the expression of sequence learning, since the learning effect that resulted was greatly improved in a follow-up block of trials presented at a higher contrast. Howard et al. (2007) also tried to boost older adults' sequence learning to the level shown by younger adults by extending the training phase they underwent, but this attempt was also unsuccessful.

Other attempts to relate implicit learning measures to processing speed in this manner have also been unsuccessful (McGeorge et al., 1997; Reber, Walkenfield, & Hernstadt, 1991). Salthouse et al. (1999) reconciled this evidence against Processing Speed theory by asserting that the low reliability of implicit learning tasks obscures the ability to detect relationships between implicit measures and other cognitive variables (e.g., processing speed and age), but acknowledged that this criticism does not stand up against the findings of Hultsch et al. (1991) and Small, Hultsch, and Masson (1995). Hultsch et al. (1991) and Small et al. (1995) found that stem-completion tasks possessed a moderate level of reliability, but still only found weak relationships between learning and standardised measures of cognitive functioning. However, Salthouse et al. qualified the application of Processing Speed theory to these results by classifying the experiments in Hultsch et al. (1991) and Small et al. (1995) as assessments of implicit memory, and suggested that "measures of implicit memory are more likely to reflect a qualitatively different form of processing than measures of implicit learning" (p.17). Such a statement controversially assumes entirely separable implicit learning and implicit memory mechanisms, and also implies that implicit memory is not influenced by slower processing speed while implicit learning is. If implicit learning is involved, surely a person taking a dual-systems perspective would agree that retrieval of this knowledge is also implicit, so it seems contradictory in this case to propose that learning could be degraded due to processing speed but memory for this learned information would remain unaffected.

Actually the nature of the criticisms above draws attention to the difficulty previous experiments have faced in their application of theories of cognitive slowing to implicit tasks, which ultimately leads to the conclusion that cognitive slowing may not be a suitable explanation for older adults' learning on tasks of this nature. Neither of the criticisms above of implicit memory tasks can be applied to the contextual cuing task. Although the presence of awareness depended on the circumstances of the detection task, in Chapter 4 it was clear that contextual cuing should not be portrayed as an example of a purely implicit task. The findings reported in Chapters 2 and 3 established that both the detection task and the explicit tests were reliable and powerful enough to demonstrate age-related differences in performance, so if a statistical relationship existed between measures of contextual cuing and processing speed it should have become evident in Chapter 3. Therefore, it is reasonable to conclude that cognitive slowing does not influence the contextual cuing deficits that are observed in older adults.

5.3 The Role of Awareness in Contextual Cuing

In addition to an age effect in baseline response latencies, in Experiment 1 there was also a difference in performance on the awareness test. While younger adults were able to consciously recognize Repeated configurations from the detection task during the explicit recognition task, older adults showed no such ability. This result is particularly striking when it is coupled with the absence of both contextual cuing and recognition in older adults in Experiment 1, because it contradicts the generally accepted notion that contextual cuing knowledge is subject solely to implicit processing. If awareness plays a significant role in contextual cuing, it becomes possible that the explicit memory decrements that occur in healthy ageing individuals may be linked to their inability to demonstrate contextual cuing in Chapters 2 and 3.

The presence of an awareness effect in the younger adults is controversial, since contextual cuing is traditionally classified as driven purely by implicit learning (Barnes et al., 2008; Bennett, et al., 2008; 2009; Chun & Jiang, 1998; 1999; 2003; Chun & Phelps, 1999; Howard et al., 2004; 2006; Huang, 2006; Manns & Squire, 2001; Nabeta et al., 2003; Peterson et al., 2002; Pollman & Manginelli, 2009; Schankin & Schubo, 2009; van Asselen et al., 2009). Experiments 5 and 8 established that this variance in results was most likely caused by the fact that the awareness tests in this thesis adopted a block-design with a larger number of test trials, which increased the power and reliability of both the generation and recognition tests and thereby improved the ability to detect participants' awareness of contextual cuing knowledge.

That being said, the fact that contextual cuing was accompanied by awareness in Experiments 1, 5, and 8 but occurred without awareness under shorter detection task conditions in Experiments 6 and 7 is consistent with the graded, dynamic, perspective of implicit learning and conscious awareness proposed by Cleeremans and colleagues (Cleeremans, 1997; 2006; Cleeremans, Destrebecqz, & Boyer, 1998; Cleeremans & Jimenez, 2002). According to this account, awareness of implicit knowledge occurs on a continuum with consciousness described as merely an aspect of a representation that is dictated by the quality or strength of the representation. Presumably, a longer detection task allows for the development of stronger higher-quality representations of configurations which eventually lead to conscious access to this knowledge. Though such an argument has great overlap with the principles of a single-system view of memory in its belief that an association between implicit and explicit learning exists -- which deems the need for making a distinction between a representation as implicit or explicit at any given point unnecessary -- the acceptance of Cleeremans' argument would still be a concession to those in support of a traditional single-systems view (Shanks & St. John, 1994). The premise that delineates the dynamic approach to memory from a single-systems account is its support of the idea that unconsciously encoded information can be less accessible, or inaccessible at some point, to the conscious system. From this perspective, it is clear that the effects of cognitive ageing extend beyond an explicit processing deficit.

5.4 Limitations and Future Directions

The aim of this thesis was to examine how cognitive ageing affects contextual cuing, and not specifically to promote the idea that contextual cuing is absent entirely in healthy older adults. Yet, given that contextual cuing was not shown at any point in any of the analyses of older participants' performance in Experiments 1, 3, or 4, there was little evidence from these data to suggest that the older participants included in this thesis were capable of learning the predictive relationships entailed in contextual cuing. It is unclear why we have repeatedly failed to obtain contextual cuing in older groups (Experiment 1, Older group; Experiment 3, Easy Detection Older Group, Difficult Detection Older group) whereas Howard et al. (2004) did obtain such an effect.

Perhaps, as discussed in the General Discussion of Chapter 3, the older adults in our Experiments 1,3, and 4 who performed poorly on the contextual cuing task were inherently different from the older participants in Howard et al. (2004). The participant-recruiting practices in our experiments were based on that of Howard et al.'s, with older individuals required to answer a series of questions about their health prior to participation to ensure that they were in good health and free from cognitive disorders. Yet it is possible that participants could have passed this screening despite suffering from an undiagnosed neurological condition (e.g. dementia). This is an acknowledged weakness of many memory studies that must rely on self-report measures of health, because they do not have the resources to monitor each participant's medical history, neurological health, and longitudinal memory data.

A discussion of the statistical power of the design of our experiments in detecting contextual cuing in general, as well as questioning the magnitude of the age-related difference shown in Experiment 1 may also provide further reason why the overall conclusions of this thesis differed from those of Howard et al. (2004). It is possible that the statistical power to detect reliable contextual cuing was compromised when an abbreviated detection task was used, but if this was case, we would not have expected the younger individuals in Experiment 1 to demonstrate such a large contextual cuing effect by the last epoch of the task (d = 0.74). A subsequent analysis of the power of the study showed that the sample size (n = 20) was extremely powerful (0.94) in detecting a contextual cuing effect of this size. Therefore, if older adults are just as capable of showing contextual cuing as younger adults, we would have expected to have seen an effect using this experimental design in Experiment 1, 3, and 4. That being said, the probability of detecting resulting performance differences that occurred between the older and younger groups (d = 0.63) in Experiment 1 was still only 62% when each group is made up of 20 participants. Howard et al. (2004) included more participants (n = 30) than we included in Experiment 1, which presumably made their study more powerful than ours. It is still important to exercise caution when interpreting whether null effects signify a true lack of a difference in performance, or merely a product of a lower power design. To minimize concerns about statistical power, it is generally accepted to include a number acceptable to achieve an effect 85% of the time, which would require each group to be made up of at least 37 participants to obtain a difference in performance with a similar effect size of the age-related difference shown in Experiment 1.

Issues of statistical power and study design are also a relevant concern when the above logic is applied to the experiments in Chapter 3, where the processing speed theory of memory was tested using between groups comparisons. Clearly these studies relied somewhat, though not solely, upon null statistical effects as evidence for making overall conclusions. The premise of these studies was that slowing down younger adults should noticeably impair contextual cuing, meaning that an ad hoc assumption would speculate that this resulting difference in contextual cuing between the younger control group and the slower experimental groups in Experiment 2 would be similar to difference between the older and younger groups in Experiment 1 if slower processing speed accounts fully for older adults' poor contextual cuing. Experiment 2 included 40 participants in each group; and therefore, exceeded the number of participants necessary for an adequate amount of statistical powerful to detect a possible difference between conditions when effect size is similar to that which resulted in Experiment 1.

Our conclusion that the minimal contextual cuing observed in our older participants is not attributable to their overall slow responding is bolstered by the findings of three previous studies that employed similar speed manipulations to alter baseline RT in contextual cuing in younger individuals. Chun and Phelps (1999), Howard et al. (2004, Experiment 2), and Manns and Squire (2001) all found that artificially slower younger participants continued to show robust contextual cuing, as seen in Experiment 2 here. Where Chun and Phelps (1999) and Manns and Squire (2001) disagreed was in relation to the effects of medial temporal lobe damage on contextual cuing. Chun and Phelps reported that individuals with amnesia failed to learn contextual associations, and concluded that medial temporal brain structures are vital to this form of learning. Chun and Phelps' conclusion is controversial because it runs counter to the assumption that the task evokes a form of implicit learning. That pattern is similar to the one observed here for the effects of aging. Manns and Squire (2001) found that amnesic participants with damage limited to the hippocampal formation showed intact learning, while only amnesic participants with more extensive damage to the medial temporal and lateral temporal lobes were impaired. Manns and Squire therefore concluded that the task is implicit, insofar as damage to the main structure controlling explicit learning/memory – the hippocampus – does not affect contextual cuing. Whatever the precise roles of the hippocampus versus other medial temporal lobe structures –our findings are not a direct measure of neural activation; however, they are also not inconsistent with either of these studies if we assume that lower levels of contextual cuing in older individuals are linked to impaired medial temporal lobe (rather than purely hippocampal) functioning.

Instead of limiting all of the memory decrements that result with age as derived from damage to a specific explicit memory system, an alternative view has emerged that describes memory deficits as a consequence of cognitive ageing or amnesia depending on whether task performance depends on associative processing, as opposed to consciousness (Chalfonte & Johnson, 1996; Chun, 2005; Naveh-Benjamin, 2000; Reder et al., 2009).

According to the associative deficit hypothesis, healthy older adults' performance decrements on certain memory tasks and not others depends on the extent to which performance relies on creating and retrieving links between single units of information, and requires integrity of the medial temporal lobe. Specifically, diminished working memory capacity (e.g., Craik & Jennings, 1992; Hartman et al. 2001; Mitchell, Johnson, Raye, & D'Esposito, 2000; Salthouse & Babcock, 1991; Zacks et al., 2000) and the atrophy of the hippocampal system (Hedden & Gabrieli, 2004; Rosen, et al., 2003), both generally accepted to occur with cognitive ageing, create the "binding" issues described in the associative deficit hypothesis.

Successful contextual cuing essentially is a definitive measure of associative binding. Evidence of contextual cuing can only occur after participants have formed an association between the location of a target letter and the spatial context of the distracter letters within a repeated configuration, and are subsequently able to retrieve this relationship later on to guide visual search or generation during the explicit test. This, coupled with the strong body of evidence corroborating hippocampal involvement in contextual cuing (Greene et al., 2007; Chun & Phelps, 1999; Park et al., 2004; Ryan et al, 2000), provides a strong argument in favour of the associative deficit hypothesis as an account of why the contextual cuing is susceptible to cognitive ageing. The findings of age-related decrements in contextual cuing that were shown in this thesis need to be extended further to incorporate possible scenarios in which learning is facilitated in the task. Based on predictions of the associative binding hypothesis, this might be accomplished by decreasing the complexity of the repeated configurations to facilitate encoding between the contextual cues and the target locations during the detection task (i.e., decreasing the total number of configurations within each block, or including displays containing fewer distracters).

Findings in Negash et al. (2007) also cannot be ignored as a possible explanation for the age-related decline of contextual cuing. Perhaps the age-related decrements in contextual cuing found in Experiments 1, 3, and 4 coincided with a certain genetic predisposition in those older adults. Some of the most robust findings of genetic associations have been between certain ApoE alleles and Alzheimer's disease. Principally associated with protein that is involved in the transport of cholesterol, ApoE ε4 has been shown to speed up the age of onset of Alzheimer's disease because it hinders neuronal repair mechanisms (McGue & Johnson, 2008). Though surprisingly, the link between ApoE and normal memory decline to date has only been shown to occur in older adults within the 50-70 year old age range (Bathum et al., 2006; Zhao et al., 2005), and has been shown to be relatively weak (Christensen et al., 2004; Hofer et al., 2002; Wilson et al., 2002). Undoubtedly, Negash et al.'s original result of a relationship between ApoE and contextual cuing impairments should be extended further to address the specific neurological consequences of being a carrier of this allele, and whether this genetic influence is only asserted after a certain age, as previous experiments suggest.

5.5 Conclusions

The evidence presented in this thesis challenges the notion that older and younger adults perform equivalently on implicit memory tasks, in particular the contextual cuing task. It also became apparent that the behavioural impairments caused by cognitive ageing cannot be explained based on consciousness of processing and slower processing speed. Therefore, it seems necessary to shift conceptions of memory to a representation with the capability to resolve why reductions in cognitive functioning occur in ageing populations and amnesic patients.

This thesis provides a strong body evidence to challenge previously accepted theories of memory, most notably the infamous implicit-explicit memory distinction, so that a clear and accurate portrayal of cognitive ageing can be obtained in the near future

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