COMMONSENSE UNDERSTANDINGS OF CAUSES OF MOTION

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ABSTRACT

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There are many findings about children's spontaneous reasoning in dynamics. These studies suggest that a non-Newtonian framework is used by students across a large age range but there is controversy as to whether pupils' conceptions represent systematic mental structures or temporary constructions. Ogborn (1985) constructed a theory of commonsense understanding of motion, which proposes a definite structure of thinking. Unlike much previous work, his theory is susceptible to testing.

This research sets out to test this hypothesis about the content and nature of commonsense ideas of motion. After preliminary work using interviews and repertory grids, a formal model of the theory was constructed which provided the basis for the collection of data in the main study. The adoption of a causal model of motion provided a template for linking primitive abstractions such as effort and support in a natural way.

In order to test a large number and wide age range of subjects (7 - 16 years), a matching pairs paper and pencil task was developed for the main study. Subjects were asked to distinguish between examples of nine stereotypical motions by comparing the similarity or difference of the causes of pairs of motions. It was then possible to test theoretical predictions of the comparisons against empirical data.

The results suggest that people's responses can be predicted by the model but that there is an improvement in the correlations with the additon of an animacy correction. An independent test was carried out where the animate nature of moving objects was varied systematically and it was found that this feature, previously neglected by the theoretical account, was an important distinction in subjects' consideration of causes of motion. As predicted, the results were similar over a considerable age range, being however better for older children than the younger ones.

Taking account both of these results and of Piaget's description of the sensori-motor period of child development, a new version of the model is proposed, and tested against the available data.

For my parents

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1. INTRODUCTION

The purpose of this opening chapter is to provide an overview of the thesis, and to explain the origins of the work. The chapter therefore divides itself into two sections. 1.1 **Origins of the Research,** describes how I became involved in this work. 1.2 **Outline of the Research,** presents a brief plan of the thesis.

1.1 ORIGINS OF THE RESEARCH

An initial interest in childrens' commonsense ideas about motion began when I was studying for a Masters Degree at Chelsea College London, and began working with Joan Bliss on a preliminary empirical exploration of Ogborn's (1984) model of a commonsense understanding of motion. Bliss (1989) had started to see if this theoretical account provided the basis of primary pupils explanations of motion and I became interested in whether similar explanations would be found in secondary school pupils' accounts of motion. I worked with a group of fourteen to eighteen year olds, some of whom were studying 'A' level physics, and found surprisingly enough that most students seemed to use the basic premises of the model to describe motion. Although the results were interesting in themselves these investigations did not provide any systematic testing of the theoretical position.

A more rigorous testing of the model began when an E.S.R.C. studentship became available and I started to work with Jon Ogborn at the London Institute of Education. It is perhaps the exception rather than the rule to be involved in testing a model in research in science education. In the event, the results of the work were able to suggest areas where the model needed elaboration and development.

1.2 OUTLINE OF THE RESEARCH

Previous research has shown that children have their own ideas about motion, as well as about other scientific concepts such as heat, light and electricity. This research has accumulated a large body of descriptive data which is not always easy to interpret. It is difficult to see how empirically to assess the merits of the various proposals that have been made about the nature of such conceptions. This thesis sets out to test a particular theoretical hypothesis about the content and nature of commonsense understandings of causes of motion.

Two versions of the model of commonsense ideas about motion were tested in three ways. A first version of the model proposed by Ogborn (1985) with ideas derived from Hayes' (1979) "Naive Physics Manifesto" was tested in two preliminary ways:-

1. By using an interview technique.

2. By using a repertory grid methodology.

A third and more systematic test was then applied to a formalised version of the model which linked the "primitive abstractions" of support and effort within a causal framework. This final test used a specially designed comparison task to elicit similarities and differences between stereotypical motions as predicted by the formalised version of the model, and provides the main body of results for the thesis. Two supplementary tests (using the same format as the main comparison task) were carried out to:-

i. assess the importance of an animacy factor in commonsense understanding of motion, and

ii. clarify the role of motions in which one object carries another.

The results show that responses can be predicted by the model, but that an animacy feature, previously neglected by the model, is an important distinction in the commonsense understanding of causes of motion. It also appears that CARRY motions are, as predicted, distinct from other types of motion, in that a carried object inherits both its effort and support from the carrier. That is, the motion of a carried object is seen as similar to the motion of the carrier itself. This result was predicted by the model.

The final part of the thesis speculates about how to improve the model, in the light of these results and of speculations about how these commonsense understandings of causes of motion develop. Thoughts about the infant's construction of ideas about the nature of objects and their motion in the sensori motor period, are incorporated into a reformulation of the model. A multi-dimensional scaling analysis using this third version supports the idea that the model can now predict to some extent the structure of thinking about motion.

2. CHILDREN'S LEARNING AND ALTERNATIVE CONCEPTIONS OF SCIENCE

The purpose of this chapter is to give some insight into the nature and status attributed to children's alternative conceptions of physical phenomena. 2.1 **Introduction** summarises how these ideas have been interpreted by a number of researchers. 2.2 **Examples of Views Children hold in common about physical phenomena** illustrates some of these alternative understandings. 2.3 **A view of the nature and status of children's conceptions** describes one way which has been used to classify studies from different areas of the physics curriculum. 2.4 **Views about Teaching and learning** describes how children's alternative conceptions are affected by instruction. 2.5 **What is the differences between children's knowledge and scientific knowledge?** specifies some of these differences.

2.1 INTRODUCTION

It has long been recognised by Science teachers that students regularly experience difficulty with certain aspects of the curriculum. Pupils' responses to questions which are designed to test understanding rather than factual recall often reveal fundamental confusions and lack of comprehension. This means that some of the most successful examination candidates have expended time and energy committing factual knowledge to memory, with apparently very little understanding of it.

A common interpretation of the alternative conceptions research (Driver and Erickson, 1983) suggests that students do not assimilate new ideas uninfluenced by existing ones. These studies illustrate that pupils have their own firmly held ideas about many science topics, and that it is these notions which they employ to make sense of their classroom activities. Watts (1982) refers to these student ideas as "alternative frameworks" rather than classing them as "wrong" or "misconceived". Nussbaum and Novick (1981) argue that when a student uses a naive alternative framework or preconception to interpret classroom experience, he or she may well give this experience meanings which are different from or in total conflict with those intended by the teacher. Some would assert that pupils have not "misunderstood" the ideas but have "understood them differently" from what was intended, resulting in a mismatch between pupils' understanding of science and formal science.

2.2 EXAMPLES OF VIEWS CHILDREN HOLD IN COMMON ABOUT PHYSICAL PHENOMENA

There has been a growing interest and a plethora of investigations which support the view that pupils have intuitive ideas about natural phenomena. A variety of studies have been conducted in such areas as dynamics, gravity, heat, light, density, electricity and many others. (For comprehensive reviews and discussion see Gilbert and Watts, 1983, Driver, Guesne and Tiberghien, 1985, Osborne, Freyberg 1985, Adey, Bliss, Head and Shayer, 1989). For example children's ideas about light show three common frameworks:-

a. Sight comes from the eyes and can 'meet' the light coming from an object.

b. Light illuminates objects so that they are "lit up" and can then be seen. The light is local to the scene and need not travel as far as the viewer.

c. A reflection is an image on a mirror or surface (and not a process by which light changes direction).

For a more comprehensive review of students' interpretations of optical phenomena see Andersson and Karrqvist (1982).

In the field of electricity, it appears that many pupils subscribe at some stage to a sequential model of direct current flow, Shipstone (1982). The relative positions of a bulb and resistance in series would affect the brightness of the bulb if a pupil were working with such a model. It would, therefore, be anticipated that the bulb's light would be weaker if the bulb were placed after the resistance in the circuit, because the current would be less by the time it reached the bulb after the effort of struggling through the resistance.

Although the evidence for these prior beliefs is abundant, it is often difficult to find any general patterns which account for their nature. Not only is it not known where such ideas come from, but there is also disagreement as regards to their structure and permanence. Should these ideas be regarded as children's 'theories', or just as their passing fancies? Thus while the research illustrates a good deal about what children think, much less is understood about why they think it.

2.3 A VIEW OF THE NATURE AND STATUS OF CHILDREN'S CONCEPTIONS

There are a variety of views taken about the nature and status of the alternate conceptions that pupils hold. They have been described by Helm (1980) amd Lawson (1989) as misconceptions and by Novick (1980) as preconceptions. The term "alternative conceptions" has been used by Driver and Easley (1978) while Gilbert, Osborne and Fensham (1982) refer to them as "children's science". The theoretical perspective of the researchers concerned largely determines their choice of nomenclature.

Gilbert and Watts (1983) have attempted to classify a number of studies from different areas of the physics curriculum in terms of their relation to the term "concept". They have chosen to place studies into three major groups which take different meanings for the term concept. The first group encompasses the "classical" view of concept; where all instances of a concept share common properties and these properties are sufficient to define the concept. The investigations of force by Helm (1980) and Za'rour (1975) have been classified as being of this kind. The notion of misconception lies within this classical viewpoint and Za'rour equates mistakes and misconceptions with erroneous beliefs about force.

Another group takes an "actional" view of concept, in which concepts are seen as active, constructive and intentional. From this point of view, there is little distinction between a concept and a theory. Of the many studies placed in this group, children's notions are commonly thought of as "alternative frameworks", (Gilbert and Watts 1983, Osborne 1985).

The final category is the "relational" view of concept, a stance intermediate between the two above. Studies such as those undertaken by Champagne et al (1981) investigating force and Duit (1981) looking at children's notions about energy have been included in this group. Gilbert and Watts identify the reason for these basic discrepancies of view taken about the nature of the research as the pre-paradigmatic character of present research. At any rate, it is clear that the initial theoretical stance taken has had a large influence on the way the results of otherwise similar researches have been interpreted.

2.4 VIEWS ABOUT TEACHING AND LEARNING

Much of the evidence which supports the claim that children have intuitive ideas about natural phenomena stems from a "constructivist epistemology" (Driver 1983, Pope and Gilbert 1983), and various groups of research workers have been particularly concerned to apply some of Kelly's notions and to develop techniques consistent with his approach in order to explore both school children's and undergraduates' constructs or concepts in science.

The constructivist view of knowledge as represented by Kelly's "Constructive Alternativism" suggests that people understand themselves and their surroundings by constructing tentative models which are evaluated in terms of their predictive power and control of events. This constructivist view of knowledge leads to the opinion that teachers should be concerned with the investigation of pupils' ideas, that children's viewpoints should play a role within the teaching/learning dialogue, and that pupils should be led to reflect upon their construction of the relevant aspects of reality.

Although there is still some conceptual and methodological clarification needed in the identification of student concepts, what effect can these notions have on the pupils' acceptance of formal science? Gilbert, Osborne and Fensham (1982) suggest three ways in which students' frameworks may interact with classroom teaching. These are:

i. The blank mind approach - where children readily and easily adopt the formal science they are taught (not a tenable position!)

ii. The frameworks held are displaced by effective instruction.

iii. The students' framework is resistant to change.

Data obtained from 'interview about instances' techniques (see chapter 3) suggests five possible outcomes from children's science reacting with school science. One of these outcomes is intermediate to those mentioned above, and is referred to as "the two-perspective outcome", in which the teacher's science view is rejected as a personal model but the teacher's science may be learnt by rote. Posner and Hoagland (1981) suggests that students may compartmentalise their knowledge, "claiming that the problem is a physics problem and therefore does not have anything to do with the real world". (A similar incident occurred during the course of my own investigations when a sixth form pupil was asked whether the speed of an object would change travelling downhill. The reply given was "Oh, that's physics. I can't remember any of my physics now".) It is possible for pupils' knowledge to run parallel with school science knowledge without any dissonance.

Driver and Erickson (1983) contend that the type of content or nature of the subject matter will affect the type of interaction that will take place between children's science and formal science. They suggest that topics such as heat, temperature and mechanics, which are areas where the pupil has access to much previous sensory information, will result in more stable frameworks, which will be more resistant to change. Pope (1982) believes that many students may be "turned off" science because of the perceived gap between the content of science lessons and their own world views.

More recent discussion has focussed around particular curiculum development projects. Lawson(1989) views children's ideas as misconceptions and regards their failure to reason scientifically as a lack of logical reasoning ability. He adopts a Piagetian position and offers a method of change based on Piaget's theory of equilibration in his theory of science instruction.

Driver (1989) takes a different view and believes that children's ideas are not misconceptions but alternative conceptions. She believes that children construct their own knowledge, a view which is not at variance with Piaget. However, Driver rejects a Piagetian basis, but herself provides no alternative theoretical framework for promoting conceptual change. She believes children's own beliefs should be elicited prior to science instruction and so a process of "cognitive conflict" ensues during instruction. In this way the children are encouraged to see the inadequate explanatory power of their own personal models and are encouraged to adopt a scientific perspective. Solomon (1989) however, comments on the Clisp project's way of promoting conceptual change:

"It seems to be expensive of both time and spirit to try so hard to bolster up ideas by clarification and exchange only to knock them down by arranging subsequent conflict situations."

diSessa (1988) argues against cognitive conflict as a way of changing children's intuitive ideas. His view is that moving to a physicist's view of reality involves "building a new and deeper systematicity" which cannot be provoked by a pedagogical strategy of cognitive conflict. He proposes that this strategy is appropriate only if one believes that commonsense ideas are structured, so that subjects' intuitive ideas need to undergo a theoretical change which can be induced by confronting the intuitive theory with counter arguments.

2.5 WHAT IS THE DIFFERENCE BETWEEN PUPILS' KNOWLEDGE AND SCIENTIFIC KNOWLEDGE?

There is a large difference between commonsense notions and a scientific description of the world, so that the two need to be bridged. Before such a bridge can be constructed the differences between the pupils' knowledge and scientific knowledge need to be clearly understood. Some of these general differences are illustrated in table 2.1 and are discussed below.

1. Differences in the construction of the knowledge

Both scientific and commonsense knowledge are social constructions but the social group which constructs scientific knowledge is totally different from and works in a different manner than the ordinary community. Scientists decide on what sorts of theories will be accepted as scientific knowledge through the publication of articles, peer review and citation. It is Ziman (1978) who clearly defines this position.

"The goal of science is to achieve the maximum degree of consensuality. Ideally the general body of scientific knowledge should consist of facts and principles that are firmly established and accepted without serious doubt.....The consensuality of such systems is tested by such strategies as the attempted confirmation of predictions or by the discovery of marginal phenomena that might prove inconsistent with accepted theories. It is important to realize that much of the research literature of science is intended theoretically - to persuade other scientists of the validity of a new hypotheseis or to shatter received opinion."

Table 2.1: Differences between Scientific and Commonsense Reasoning

SCIENCE	COMMONSENSE
1. Critical consensus	Solidarity
2. Explain in new terms	Account for in current terms
3. Deal with particular areas and well defined fields	Everything
4. Systematic criticism Systematic methodology	Ad hoc method (bricolage)
5. Prediction (general)	Prediction (particular)
6. Frozen, technical, precise language and definition	Live, non technical, fluid language and definition
7. Taught	Picked up
8. Understanding explicitly in terms of laws.	Understanding tacit
9. Causality is a relation between system variables	Causality is a chain of actions of objects

2. Differences in terminology

Driver, Guesne and Tiberghien (1985) suggest that children's science differs from scientists' science in that young children are concerned with constructs which follow directly from everyday experience and are not concerned, like the scientists, with conceptions which have no physical reality, such as potential energy. Thus science introduces novel technical terms, where commonsense uses old and familiar terms, to explain the world.

3. Science deals only with knowledge within a well defined area

The process of science is to study a particular phenomenon which has definite properties which can be isolated, reproduced in time and space and whose behaviour can be predicted. Predictions in science are described in terms of experimental laws and theories. Because they aim at exactness, and generalising, scientific accounts are highly restricted in their application. By contrast, commonsense is satisfied with rougher, adaptable rules of thumb, so as to deal with a wide range of phenomena.

4. Differences in methodology

Commonsense is not so systematically and rigorously tested as is formal science. Cohen and Manion (1985) suggest that the layman bases ideas on haphazard events and uses them in a loose uncritical manner ... "When he is requested to test them he does so in a selective manner, often choosing only that evidence that is consistent with his hunches and ignoring that which is counter to them". They hold that the scientist however constructs theories carefully and systematically.

5. Science predictions are more general in nature

Science sacrifices 'experiential' descriptions for the sake of abstract universality. While children focus on limited aspects of given structures and as Driver et al (1985) assert, interpret phenomena in terms of absolute properties or qualities ascribed to objects rather than in terms of interactions between elements of a system. For example, some children chose an iron container to keep ice cold for as long as possible because of the specific properties of iron (e.g. it is a solid, or it is naturally cold): they tended not to think about the problem in terms of the interaction between the ice and the container and the ambient air.

6. Differences in language

Cohen (1978) suggests there is a difference in the use of language. In everyday usage, there is a vague diversity of meanings attached to given words, so that popular language is not well adapted for the purposes of rigorous reasoning. "It not only makes contradiction possible by the use of the same term to denote entirely different things on different occasions, but two perfectly compatible views may seem contradictory unless we have a specially developed language which enables us to make the proper distinctions between them and thus reconcile them."

7. Taught versus picked up knowledge

The idea that commonsense ideas are not taught in the sense of scientific notions is illustated by the prevalence of the same sorts of ideas found in children's thinking across wide ages and countries.

Driver el al (1985) comment:

"There are a number of ideas which are quite prevalent and influence children's thinking about a range of situations. One of these more dominant notions is the association made between the action of a force and resultant motion. Not only does this idea appear in pupils' interpretations of the motion of objects in their everyday world, but we have also seen evidence that the idea influences their thinking in other areas. In the case of fluids, for example, we have seen how pupils tend to consider pressure in one direction only - the direction in which some 'action ' is applied. Problems pupils have in appreciating the intrinsic motion of particles may also stem from their belief that motion requires a force to maintain it."

8. Explicit versus tacit knowledge

Both commonsense reasoning and scientific understanding is active in nature. Both types are concerned with a choice between different courses which are open to an individual to obtain a predicted and desired result. One of the characteristics of living things is that their actions are directed towards the future but with commonsense all this is hidden in the process of life but becomes plain and explicit in the pursuit of scientific laws.

9. Differences in use of causality

The layman's concern with such relationships is loose, unsystematic and uncontrolled. The chance occurence of two events in close proximity is sufficient to evoke a causal link between them. Science however drops the popular notion of cause and effect in its effort to formulate abstract universal laws. It therefore seeks a mathematical formulation of invariant relations, from which the numerical results of measurement can be deduced.

Driver et al (1985) suggests that commonsense thinking follows a linear causal sequence and cites the following example:

".... in considering a container being heated, they think of the process in directional terms with a source supplying heat to a receptor; whereas, from a sicentific point of view, the situation is symmetrical with two systems interacting, one gaining energy the other losing it. In mechanics, as we have seen, pupils tend to think of a force, or action, producing an effect such as motion; the reciprocal nature of the forces acting (i.e. Newton's third law) is not easy to appreciate from this perspective since it requires pupils to abandon this sequential way of thinking with its 'preferred' direction."

Table 2.1 has summarised some of the differences between commonsense and scientific reasoning. It must be remembered however that commonsense forms the basis from which scientific reasoning develops. The interesting question is how commonsense notions develop? Ziman (1978) suggests:-

"The fundamental continuity and coherence between the sense of everyday reality acquired in childhood and the reality of the scientific world picture is not an illusion. Science uses the same mechanisms as in the growing child - sensori motor coordination of observation and experiment, pattern recognition and the mental transformation of images, communication with a world of 'others' and tests to select consensual conceptual schemes - not merely to implant this sense of reality into its practitioners but also as a means of acquiring uniquely faithful knowledge of the material domain. Despite numerous mistakes and misconceptions, the child constructs a picture of his immediate world that is fundamentally reliable and worthy of belief. It is difficult to deny the same qualities - and possible defects - to the picture of a much wider world created by the larger social instrument of science."

2.6 CONCLUSION

To summarise, both children and scientists have ideas about how and why the world works and the actual meanings of scientific terms but the pupil's ideas and meaning can be quite different from those of the scientist. Hence the empirical data suggests that childrens ideas should be taken seriously in their own right and investigated more fully with a view to producing a new range of pedagogical strategies which would encourage conceptual change.

3. A REVIEW OF RESEARCH IN DYNAMICS

There are three sections in this chapter. The **Introduction** describes the controversy surrounding the interpretation of commonsense ideas about motion. Then **A Review of some Research in the Field of Dynamics** gives a detailed account of selected work in the area, while the final section, **Conclusions,** summarises the various positions taken about the nature of the knowledge which contributes to a commonsense understanding of motion.

3.1 INTRODUCTION

The common features of causes of motion, which is the focus of interest here, found by many studies employing different methodologies, seem to be that:-

i. Motion needs a force to start it off and,

ii. Motion stops when this force wears out,

These ideas can be found in subjects' explanations of motion across a number of nationalities and over a wide age range. It is also clear that these ideas are not easily changed by formal physics tuition (Viennot 1979a).

Researchers however do not agree about how commonsense ideas about motion arise or should be understood, and consequently interpret their results in different ways (see chapter 2). Five different investigations are considered below, to illustrate some of the current controversial issues in this field, particularly as to whether it is possible to look for some more general knowledge structure in everyday thinking about motion.

3.2 A REVIEW OF SOME RESEARCH IN THE FIELD OF DYNAMICS

3.2.1 Introduction

The five studies below are divided into three groups, according to the methodologies they use to probe subjects' understanding of motion. These are:-

i. paper and pencil questionnaires.

ii. research on actions (student's actions rather than propositional knowledge is tested), and

iii. the interview about Instances technique,

Different aged subjects with differing amounts of physics tuition were studied and these details together with the theoretical perspective of each piece of research are summarised in table 3.1.

Table 3.1: A summary of major features of selected pieces of research in dynamics

MAIN RESEARCH METHOD	TECHNIQUE	THEORETICAL PERSPECTIVE	SUBJECT TYPE	RESEARCHER
1. PAPER AND PENCIL QUESTION-NAIRES	a. Paper and pencil questionnaire set in a traditional physics format.	Students spontaneous reasoning different to physicists and can be characterized in some way.	Late secondary and under-graduate physics students.	Viennot (1977)
	b. Questionnaire set to test understanding of every-day motions.	Adopting a methodology which could look for evidence of a more general abstract coherent theory of commonsense thinking about motion.	Secondary school pupils, Science and Arts Undergraduates and Biology and Physics G.C.E. students.	Vasconcelos (1987)
2. RESEARCH ON ACTIONS	a. Subjects interacted with a computer game called TARGET. They had to control the movement of a dynaturtle on the screen.	People have their own "Intuitive Physics" - making use of psychological primitives to understand world.	11-12 year olds and under-graduates.	DiSessa (1980)
	b. Subjects asked to push and drop objects in order to hit certain targets.	Subjects have a systematic intuitive theory of dynamics.	Under-graduates.	McCloskey (1983)
3. INTERVIEW ABOUT INSTANCES	Pupils asked to talk about pictures of different pre-selected concepts. All interviews taperecorded.	Students concepts of force, gravity and friction are different to physicists as they construct their own ideas about physical reality.	7-19 years	Watts (1983)

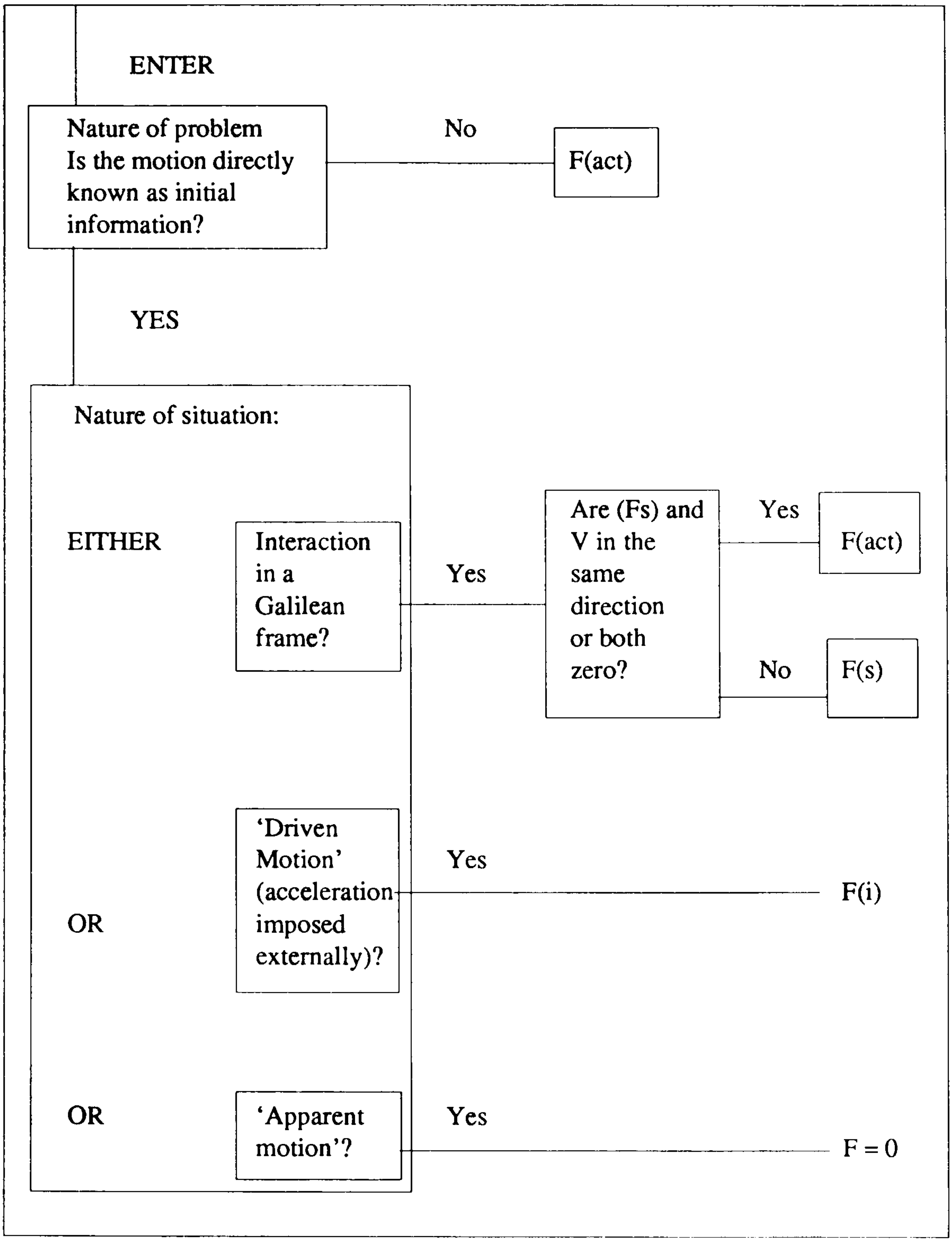
3.2.2 Paper and Pencil questionnaires

3.2.2.1 A Questionnaire study using standard physics examples

A questionnaire study undertaken by Viennot, (1977) was designed to examine the intuitive aspects of students thinking about force, energy and motion and to describe and formulate that thinking in order to improve the teaching of dynamics. The questions were constructed to avoid dependence on mathematical skills and concerned the trajectories of balls and the oscillation of springs. They were only chosen after a preliminary exploratory phase when ideas for test items were collected from interviews and teaching experience. The test information was presented both diagrammatically and descriptively. Diagrams were drawn in a traditional physics manner with velocities and vectors clearly marked. The questions therefore had a similar flavour to those presented in a traditional academic physics test.

The results showed a high frequency of similar responses among the large number of students tested, which were at variance with "expert"physicists' views. There was also little variation between samples of students tested. Viennot found that students used a small number of kinds of concept of force. She was able to describe them, and to propose a model for when they were used.

Table 3.2: Viennot's Model of spontaneous reasoning in dynamics summarising the properties of the "Force of Interaction" and the "Supply of Force"



F(act) = Force of Interaction. F(s) = Supply of Force. F(i) = Inertial force

The model as shown in Table 3.2 describes two types of Forces namely - the 'Force of interaction' and the 'Supply of Force'. Table 3.3 summarises the nature and property of these 'forces'.

Table 3.3: Different notions of "force" and the characteristics associated with them by students

	Typical Formulation	Physical Nature	Local-ization	Model
Force of interaction F(act)	'Force acting on the mass'	Orientated (vector-ial?)	Function of position	F(act)=ma a=acceleration
'Supply of force F(s)	'The force of the mass'	Mixed scalar-vector. Force - energy confu-sions	A property of the whole motion: spatio-temporal delocaliza-tion	F(s) = av
Inertial force F(i)	'Inertial force'; 'Inertial reaction'	Orientated (vector-ial?)	Occurs at an instant: temporal localiza-tion	F(i)=-ma(e) a(e)=exter-nally imposed accelera-tion

Viennot's model distinguishes between two types of 'force' as well as inertial force which are all concepts recruited to explain motion.

1. Force of interaction

Viennot describes the "force of interaction" in the following way "This notion is talked about as 'the force acting on ... [the mass]'. It is taken to be sufficient to explain motion when the force acts in the same direction as the one in which the motion occurs". This notion of force is applied when no intuitive data is presented in a problem concerning motion.

2. Supply of Force

A"supply of force" is used to explain motion where there is no immediate visible cause, for example a ball flying through the air after it has left the thrower's hand. The cause has now passed into the moving body and students refer to 'the force of the mass'. Viennot concedes that with this motion it is not clear whether students actually think of a force per se or are imagining something closer to energy. She suggests, "This notion, part Vector and part Scalar, is reminiscent of the notion of 'impulse' in ordinary language and of 'impetus' in pre-Galilean dynamics".

Viennot concluded that students use these different notions of force depending on the questions asked. What is interesting to note is the context dependent nature of the responses made by the students. The same effect has also been found by Larkin and Rief (1985) when they examined the differences between novice and expert physicists' responses to particular problem solving exercises. Although Viennot set out to describe students' spontaneous reasoning in dynamics, the design of the questionnaire was such that it could have persuaded the students to formulate their responses in school-like terms. Her model of student reasoning has a scientfic perspective. It does not necessarily capture the nature of spontaneous reasoning about "everyday" situations, despite the fact that she also proposed that the scheme used by students is widespread and self consistent. Viennot's work was one of the earliest studies in this field and has contributed to the recognition of the type of difficulties students experience when studying dynamics. Despite the importance of her systematic investigation into spontaneous reasoning and the production of a model of thinking about motion Viennot's work only points the way towards the building and testing of models of **everyday** conceptions about motion.

3.2.2.2 Questionnaire probing subjects ideas about forces in 'everyday' type motions

The second study to be discussed was developed in response to the diversity of results which had arisen from the previous research in dynamics. Vasconcelos' (1987) theoretical position was that students' intuitive or commonsense ideas are structured, and that these ideas can be elicited from students by means of a questionnaire if it is designed to probe their understanding of ordinary motions. The situations chosen for the students to explain in terms of forces were kicking, jumping, falling, throwing and rolling movements. Students were also asked to describe the forces present when a number of objects were at rest. In this way she proposed to obtain a better understanding of students' "spontaneous reasoning" than previously achieved with Viennot's (1977) study.

Vasconcelos conducted the survey with subjects from the secondary school age range through to undergraduate and postgraduate level. Some of these students had received formal physics tuition and so she was able to identify differences between students with and without physicsteaching. Vasconcelos described the ideas associated with forces in the following way:-

"Impulsive forces are present when situations involving kicks or throws are presented. Once the motion has been started, there is a force along the direction of the motion. This idea is shown by a majority of pupils with no physics teaching and persists over some years of formal instruction. Pupils do not usually consider a downward force in the direction of gravity but this idea increases with the amount of Physics teaching. Forces of resistance are rarely mentioned by arts students, and even with formal physics tuition only frictional forces between masses are usually considered; air resistance is a force generally discounted".

Subjects were also asked to describe the forces associated with a number of objects at rest such as objects on the ground, on a table, on a sloping surface and hanging by a string. Forces of gravity and of support were neglected by subjects who had not received any recent Physics tuition. There was only a substantial increase in the use of forces of gravity and of support with physics undergraduates. In general, the students' view was that there was no force present at all for objects found at rest as opposed to the physics picture of the presence of two opposed forces.

It appears that objects which are at rest and are supported do not need forces to maintain their position, and in addition ideas of resistance to motion (i.e. notions of friction) only start to appear after some physics tuition. Only then is gravity considered more frequently.

Vasconcelos' work has given more detailed information about the differences between a commonsense understanding of motion and that of the physicist's view of reality. Her study highlights the "co-existence of intuitive and 'acquired' (and 'accepted') notions within school instruction" and suggests "that physics teaching, at least up to the end of its compulsory level, does not change students' previous notions very much". Vasconcelos study illustrates a need for further clarification of the nature and content of students' intuitive ideas about motion.

3.2.3 The computer as a tool for assessing children's ideas in dynamics

diSessa's (1981b, 1986) theoretical position is that people have their own "Intuitive Physics" which is learned from experience in the world. He wished to investigate these ideas through students' actions rather than probing their propositional knowledge, so one of his empirical studies (1981a) used a computer game called Target to test pupils ideas about moving objects. The students had to direct a 'dynaturtle' (which obeyed Newton's Laws) to hit a target. Most of the students, aged between 11 and 12 years, had no formal physics training but had previously been given tuition in the computer language LOGO (four hours a week for eight weeks). The data diSessa collected were computer records of the games the children played, with extra notes containing their individual comments and details of any intervention made by the observer,throughout the games sessions.

His main findings were that the subjects expected the dynaturtle to move in the direction it was last pushed. This is in keeping with other reported work that motions take place along the direction of the force. He called this the 'Aristotelian corner strategy' and found that students were very surprised and perplexed when it did not work, and were also reluctant to abandon the idea. He also reported that even M.I.T. freshmen, after a Physics course, had used the same strategy as the younger children.

diSessa explained these results in terms of the nature of the physical world, where the effects of friction lead to behaviour which supports Aristotle's view and denies Newton's conceptions, so that intuitive and classroom physics are disconnected in the child's mind. He has more recently (1988) given a fuller account of this unconnected intuitive knowledge about motion which he has described as a number of 'p-prims' (short for phenomenological primitives). Some of these are reproduced in table 3.4.

Table 3.4: Table of p-prims as suggested by diSessa (1988)

Name	**Key Attribute**	**Prototypical Circumstance**
Ohm's Law	Agency (also "resistance")	Pushing a box with variable effort on different surfaces
Force as a mover	Violence	A throw
Continuous force	Steady effort	A car engine propelling a car
Dying away	Fading amplitude	Sound of a struck bell
Dynamic balance	Conflict	Equal and opposite competing forces
Overcoming	"Success"	Greater force overcomes weaker

diSessa suggests that these phenomenological primitives can be understood as simple abstractions from experience, which are felt to need no explanation. He argues against McCloskey's view that they possess a theory-like structure, see also (3.2.4).

An interpretation of diSessa's p-prims is that they could be connected within a causal framework. He himself defines causality with his "Ohm's law" p-prim. This he declares to be the "most fundamental and pervasive p-prim". (It is curious that he has adopted a scientific nomenclature for such a basic conceptual unit). Ohm's law consists of an **agent** exerting some **effort** to achieve a **result** through some **resistance**. The ingredients he has specified for this primitive describe a causal mechanism which resembles the experiential gestalt of causation as described by Andersson (discussed in section 6.1.1.2).

Two more p-prims which he calls "Force as a mover" and "continuous force" are regulated by "Ohm's Law". In my opinion, he uses these extra p-prims to make a distinction between two different types of effort. "Force as a mover" denotes an external source of effort as found in a throw, while the cause of "continuous force" is found from within the moving object itself e.g. a car engine propelling a car. It seems that these extra 'p-prims' fit within a causal framework where they distinguish agents of motion by the differences between the sources of force or effort they provide.

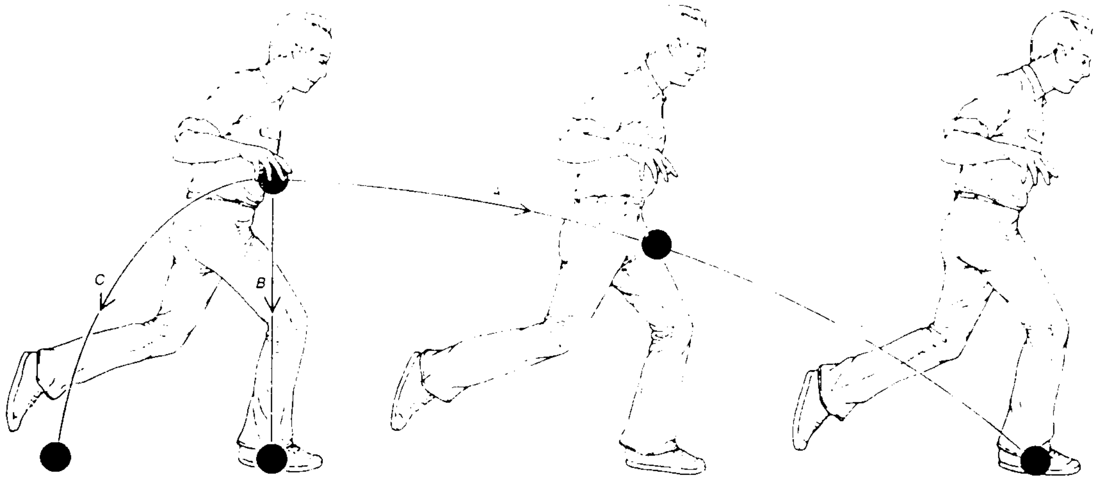
His arguments about "dynamic balance" and "overcoming" involve students' ideas about gravity, and he recruits these particular primitives to explain falling. With "dynamic balance" the student assesses which of the forces is the stronger. One force is in the upward direction, in the case of a ball thrown into the air, while the second force acting on the ball, in the downward direction, ie gravity. When gravity is perceived as the stronger force, the ball falls to the ground. This type of reasoning implies that gravity is an agent of motion and that all movement must have some cause which is supplied by an agent. The primitive of dynamic balance therefore appears to be to do with the attribution of cause rather than another unconnected component of intuitive reasoning.

3.2.4 Theories in action

McCloskey's work (1983) led him to suspect that intuitive beliefs about motion play a role, not only in people's thinking about hypothetically moving objects, but also in their interaction with moving objects. These intuitive beliefs "appear to be grounded in a systematic intuitive theory of motion that is inconsistent with fundamental principles of Newtonian mechanics". In order to systematically investigate the relation between beliefs and actions McCloskey devised two types of tasks to see if intuitive ideas about motion might influence how high school and college students performed the tasks.

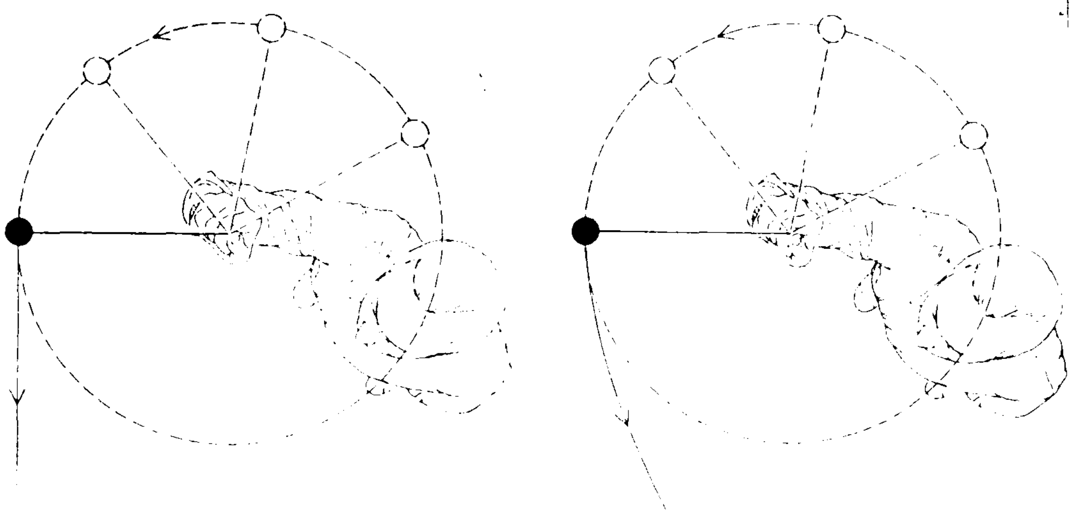
One of the tasks was to investigate through actions intuitive beliefs about the motion of dropped objects. The other task was to investigate subjects' ideas about circular motion when they were asked to push a small object across a table so that it would pass through a 90 degree segment of a circular ring planted on atable. (See Figures 3.1 and 3.2.)

Figure 3.1: McCloskey's Action Experiment with a dropped ball

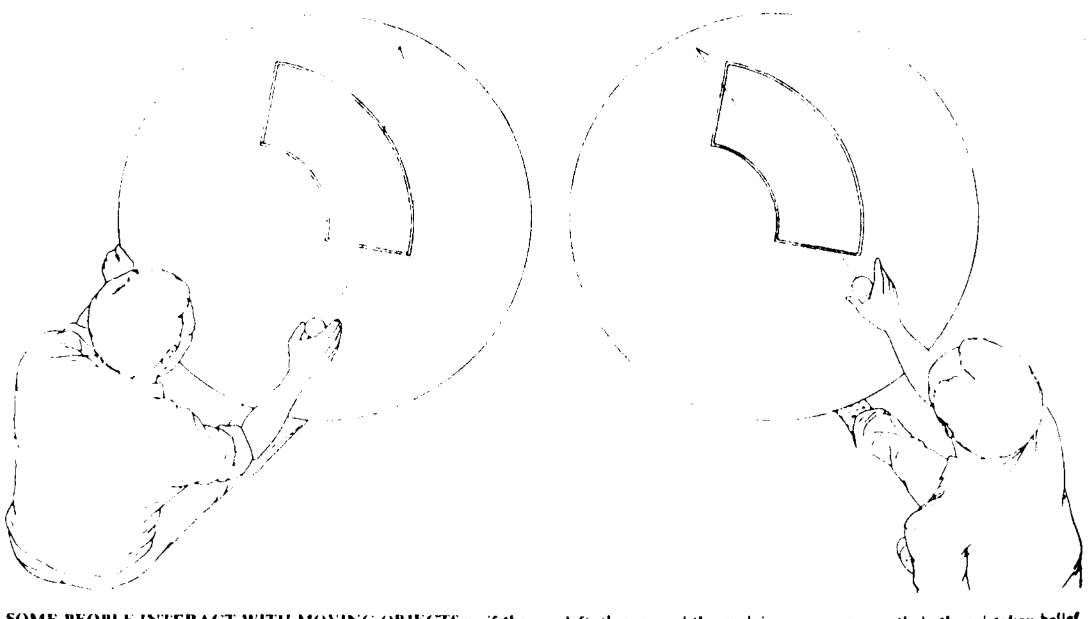


BALL DROPPED by a running person continues to move forward at the same speed as the runner. The forward motion combines with a steadily accelerating downward motion to produce a parabolic trajectory (*A*). Intuitive beliefs about the motion of objects do not always correspond with physical reality. The author and his colleagues asked college students where a ball would land if it were dropped by a walking person. Only 45 percent of the students knew the ball would travel forward as it fell. Forty-nine percent thought the ball would fall straight down and land directly under the point where it was released (*B*); 6 percent thought the ball would move backward as it fell (*C*).

Figure 3.2: McCloskey's Action Experiments with circular motion



CIRCULAR IMPETUS, according to the impetus theory, is imparted to an object when the object is moved in a circle. Hence the impetus theory incorrectly predicts that a ball whirled at the end of a string will continue to follow a curved path if the string breaks. Actually the ball will move in a straight line along a tangent to its original circular path, beginning at the instant the string breaks. Fifty-one percent of the college students who were asked to draw the path of the ball after the string breaks sketched the path correctly (*left*). Thirty percent, however, thought circular motion would persist and the path would be curved (*right*); 19 percent gave other incorrect responses.



SOME PEOPLE INTERACT WITH MOVING OBJECTS as if the objects could be given circular impetus. A 90-degree segment of a ring was painted on a table, and experimental subjects were given a small "puck" with a ball bearing that would enable it to roll smoothly across the table. The subjects were asked to push the puck up to one edge of the ring segment and release it; the task was to make the puck cross to the other side of the segment without touching the curved sides. Twenty-five percent of the subjects tried the strategy at the left: they moved the puck in an arc, apparently in the mistaken belief that the object would continue to travel in a curved path as it moved through the ring segment. The broken line, which represents the path of the puck after it was released, shows that this strategy invariably failed. Sixty-seven percent of the subjects applied the correct strategy that is shown at the right: they aimed the puck so as to take advantage of its straight-line trajectory after it was released. The remaining eight percent of the subjects tried other unsuccessful strategies.

In the first task undergraduate students were asked to walk across a room and while they were walking to drop a golf ball so that it would hit a target marked on the floor. Only 45% of the students acted as if they knew the ball would travel forward as it fell. 49% acted as if the ball would fall straight down and land immediately below its' point of release while 6% acted as if the ball would move backwards as it fell.

In Task 2, 25% of the subjects moved the puck in a curved path before releasing it, appearing to believe that it would continue to curve after release and so would follow the arc of the ring segment, and indeed were surprised when the puck failed to curve.

McCloskey suggests that the undergraduates viewed circular motion as not being fundamentally different from motion in a straight line. Both forms of motion are generated by imparting the appropriate impetus to an object. However a pupil working with a Newtonian framework would realise that for an object to move in a circle, it must be acted on constantly by an outside force that tends to deflect the motion from linearity.

McCloskey also asserts that his theoretical position can also account for the intuitive belief that a carried object falls straight to the ground, when it is dropped. He draws this conclusion from subjects explanations about why some objects do not automatically acquire impetus. Subjects said that objects only acquire impetus when they are pushed or thrown but not when they are carried. There is therefore no impetus to send an object forward when the carried state stops and so it just drops straight down to the ground. There is however an alternative interpretation for this belief. It could be assumed that there is only one force, namely gravity acting on a falling object, which acts only in the downward direction. This means that the belief that an object falls straight down to the ground without travelling forward at all could just be another example of people believing that an object travels in the direction of the force acting on it. Another interpretation is also possible, for this commonsense understanding of motion, which is that falling is simply caused by a lack of support.

McCloskey's methodology is an important and useful contribution to our understanding of subjects' intuitive ideas in dynamics. He believes there is some structure to these intuitive notions. His studies suggest that students' errors are systematic, and he remarks that their intuitive theory bears a striking resemblance to the pre-Newtonian theory of impetus (an idea previously proposed by Viennot). His technique has removed problems of mathematical manipulation, interpretation of graphical data and diagrams from the understanding of the problem. There are however difficulties in adopting an historical model to describe spontaneous reasoning in dynamics, in that the model does not account for all the different responses found in the literature. A fuller critique of the use of historical models is given in section 4.2.2.

3.2.5 Employing an Interview about Instances technique

Another set of studies set out to investigate the differences between the ideas students have from those of the physicist, about certain concepts such as force, gravity and friction.

Osborne and Gilbert (1979) and Watts (1983), developed their own methodology, the Interview-About-Instances technique, to probe students' everyday conceptions about motion. Their technique consisted of tape-recorded discussions with pupils using a series of picture-cards each of which depicted a one-word concept which the researcher wished to investigate.

The following questions were used in conjunction with the pictures to gain insight into the children's conceptions.

> "Do the situations represent examples of your concept of force?".
>
> "Why do you say there is a force here?".
>
> "What would your example of force be?".

In order to discover what pupils everyday knowledge was like, secondary school pupils with no physics tuition or very little formal physics teaching were chosen. The analysis attempted to interpret what the students understood about a particular word concept. It was found that the language that the chidren used to describe these concepts was not that of the physicist.

The children's ideas of force were applied more in an everyday sense, as illustrated by the following example of a man pushing a car which has broken down. Children explain that there is a force acting in this situation because the man 'is forcing the car'. Subjects adopted a human perspective when describing force, for example they saw no forces acting on a riderless bicycle.

The researchers concluded that children have their own everyday meanings for Physics terms which are acquired before any Physics teaching, and that these meanings vary and can be contradictory. Although Watts sees these results as children's individual attempts to make sense of the world, he also identifies a number of common ideas. With respect to the notion of Force, Watts (1983) identified eight different alternative frameworks which can be summarised as the following three ideas:

a. Constant motion requires a constant force (similar to diSessa's p-prim 'force as a mover').

b. The amount of motion is proportional to the amount of force. (Similar to diSessa's p-prim called 'Ohm's Law').

c. Forces are to do with living things.

A number of meanings of gravity were also reported, including:-

i. A force which requires a medium to act through (usually the air).

ii. Gravity is different from weight.

iii. Gravity is the result of the air pushing down.

iv. Gravity increases or decreases with height.

One of the problems with this technique, identified by Osborne and Gilbert themselves, is the difficulty of selecting a representative set of examples for each concept. The principal question is: How many pictures of different actions are needed to sufficiently explore the boundaries of each concept? It is more likely that older subjects will be able to generalise about the essential qualities of each concept and will need to discuss fewer examples, while younger children could well focus on irrelevant details. Gilbert and Watts tried to overcome the last problem by presenting the children with very simple matchstick drawings, free of any extraneous detail.

The studies using the Interview about Instances technique tried to capture the essence of certain concepts connected with motion but were not trying to see how these ideas were connected to each other. The results of the studies give us some characteristics of forces which do not contradict other evidence but this does not help us to see a pattern of reasoning beyond the given explanations. One interesting idea is that for younger students the notion of force is connected with living things. This raises the question of the connection between animacy and motion, and whether such a connection is only found with young children.

3.3 CONCLUSIONS

Researchers agree that students have their own ideas about how and why things move, which are different from a physicist's view of reality. However there are differences of opinion about how these alternative ideas should be described. Viennot does not believe that spontaneous reasoning in dynamics is similar to a scientific account of reality. She does propose however that this type of reasoning is structured in a similar way to a scientific understanding of motion and indeed characterises spontaneous reasoning in the form of "scientific laws".

Vasconcelos does not share Viennot's opinion and proposed that a deeper understanding of students' ideas about motion could be achieved if these ideas were not formalised in scientific terms. McCloskey compares everyday ideas to those found in history and uses the Impetus Model as an explanation of the nature and structure of everyday ideas about motion. He does nevertheless agree with Vasconcelos and Viennot that commonsense explanations have some theoretical structure.

diSessa argues the case for phenomenological primitives to explain motion, while Watts stresses the importance of ordinary language in his description of childrens' conceptions. These positions are all reflected in the methodologies chosen to investigate everyday understandings of motion. Fundamental assumptions about the nature of this knowledge are also made by the researchers when interpreting their results. These can be listed as follows:-

1. The ideas are learned from experience (Watts).

2. The ideas are consistent and can be structured and described as a model or a theory (McCloskey).

3. Commonsense notions are not structured but people construct an understanding by making spontaneous and shifting parallels among phenomenological primitives (diSessa).

4. Viennot offers no fundamental explanation but suggests that the knowledge used depends on the types of questions asked and is therefore context dependent.

5. Vasconcelos supports the view that commonsense knowledge is highly structured, but does not hold that it can be adequately explained by a historical model. She takes a more psychological view point arguing that "ever present" forces such as gravity and friction are taken for granted and are not needed to explain everyday motions.

It is difficult to see how to empirically test the relative merits of each of these positions. The following chapter argues for the construction of commonsense models of thinking about motion, which are open to test, to answer more specific questions about the nature and content of a commonsense understanding of motion.

4. THE NEED FOR MODELS OF THINKING ABOUT DYNAMICS

This chapter is in five sections. The **Introduction** poses questions about what would be involved in building and testing models of a commonsense understanding of motion. The second section **Previous characterisations of commonsense ideas** explains how these ideas have previously been described and the questions which such classifications raise. The third part, **The need for a closer look at the nature of mental representations in dynamics** suggests that investigation of models of thinking in dynamics might lead to the testing of the hypothesis that pupils' conceptions represent systematic mental structures. The fourth section, **Building a Model of Thinking in Dynamics** looks at Ogborn's model of commonsense ideas about motion while the final section **Testing the model** explains why this theoretical account is a good candidate for further examination and so why it provides the main focus of investigation for this thesis.

4.1 INTRODUCTION

There are a variety of questions which need to be distinguished, in order to consider what would be involved in proposing or testing a "model" of thinking about motion.

The first level of discussion concerns the nature of knowledge about motion itself and is focused around the following questions:-

1. a. Is a commonsense understanding of motion structured and internally consistent? If so:-

   b. What would be the units or primitives of such a structure?

   c. What holds the pieces of the structure together? and,

   d. How do such commonsense ideas develop?

A second level raises questions of a more general nature.

2. a. Are there more generalised thinking schemes at the root of such models? If so:-

   b. What would these general schemes look like?

   c. Do they provide any clues about the construction of an ontology of commonsense? and,

   d. What sort of information could be obtained about the strength and stability of students' beliefs from testing such models?

Although some of the above problems have been discussed in the past, the different answers that have been given have remained at the level of opinion or pre-supposition. One line of advance would be to propose and test a model of thinking about commonsense ideas of motion. Such a model has been suggested by Ogborn which, unlike much previous work, is susceptible to testing.

4.2 PREVIOUS CHARACTERISATIONS OF COMMONSENSE IDEAS

4.2.1 Children's ideas are non-Newtonian in nature

Some research findings (Clement 1982 and White 1984) suggest that there are two major differences between Newton's model of reality and a commonsense understanding of motion.

1. Children expect motion to take place in the direction of the force and,

2. Frictional forces are not taken into account in a commonsense understanding of motion.

The purpose of this discussion is not to comment upon these ideas in detail (see Chapter 3) but is to illustrate the limitations this type of characterisation of children's intuitive thinking about motion. Classifying children's ideas as non-Newtonian only illustrates some of the differences between a commonsense understanding of motion and a scientific model. It does not give an account of all the empirical data or of how these commonsense ideas could have arisen. It does not attempt to answer questions about:-

1. the nature of this commonsense knowledge,

2. how we start to understand a world of still and moving objects or,

3. how this commonsense knowledge could be investigated further.

4.2.2 The use of Historical models to describe commonsense reasoning

In order to make sense of the large amount of empirical data collected about children's ideas in dynamics, some researchers have adopted the use of historical models to try and capture more of its flavour. The type of "misconceptions" found in student thinking have been compared by Clement (1982) to ideas discussed by Galileo, while Champagne (1983) has suggested that the learners' ideas are more Aristotelian in nature, as have Driver and Easley (1978). Saltiel and Viennot (1984) have compared subjects' understanding to the impetus theory, a view also adopted by McCloskey (1983) and Sjoberg and Lie (1981).

i. The Aristotelian model

What sort of evidence has contributed to the classification of pupils ideas as Aristotelian? One would expect to find a number of Aristotle's postulates present in children's explanations of motion, but researchers have mainly drawn on the presence of two notions as sufficient reason to describe the thinking as Arisototelian. These two ideas are:-

a. Motion needs a force and

b. Motion takes place in the direction of the applied force.
(The elicitation of these notions has been described in chapter 3).

Any more complete comparison of children's ideas with Aristotelian thinking, however, presents problems. The latter is far more sophisticated than children's intuitive understanding of motion, and not all the elements of the theory are found in subjects' explanations. Aristotle's kinematics utilises Euclidian geometry to provide an abstraction of the space in which motion takes place. Motion is analysed using notions of space (position and change of position) and time. Wartofsky (1968) comments upon Aristotle's abstraction of the exertion or force of motion in the following way.

"By delimiting itself to position and change of position, the geometric-kinematic description eliminates also all reference to the effort of motion,all the experience of exertion or direction. It retains them only by introducing another mathematization of experience, in the arithmetic concept of time, as itself constituted of identical units, in additive sequence, such that two are twice as long as one, and four twice as "long" as two".

In my opinion Aristotle's theory does not have the strong place for force (effort) attributed to it by those who compare children's reasoning to it. Aristotle, in his theory, also described the nature or form of objects and suggested that all things tend to maintain themselves in a state which is in accordance with their form. Aristotle however recognises that objects can be moved from their natural position, these types of movements then being conceived of as 'violent' motions. This idea can be illustrated by considering the example of a rock thrown into the air. Its initial ascent is caused by a violent motion but once the force of displacement stops then natural motion takes over. This can be described as the force which returns the rock to its natural condition of rest. There is no strong agreement in the literature that children are reasoning in terms of natural motions which return objects to a state of rest.

ii. The Impetus model

One of the problems with comparing children's ideas with impetus theories is to know which version of Impetus theory to use. Saltiel and Viennot (1985) question the utility of the comparison made between historical models and commonsense ideas, firstly because the models do not account for all the different responses found in the literature and secondly, because a better understanding of children's ideas has not been achieved using this type of account.

An important issue is raised however, by comparing commonsense ideas to past scientific models. Can a commonsense understanding of motion be described as a structured entity? McCloskey (1983), who has favoured the use of Impetus theory to describe a naive understanding of motion, takes a strong position about the structured nature of this knowledge.

"We show that ... people develop on the basis of their everyday experience remarkably well-articulated naive theories of motion. Further we argue that the assumptions of the naive theories are quite consistent across individuals. In fact, the theories developed by different individuals are best described as different forms of the same basic theory".

4.2.3 A-historical view

diSessa (1988) argues against McCloskey's use of the Impetus model to describe "intuitive physics". He believes it to be a misleading representation, and that "intuitive physics" is a fragmented collection of ideas, with none of the commitment or systematicity that one attributes to theories in the history of science or in professional practice.

In my opinion, commonsense reasoning about motion is not as disconnected as diSessa proposes because:-

i. there could well be a causal structure underlying diSessa's phenomenological primitives as argued in section 3.2.3, and

ii. thinking about causes of motion has provided a first step towards formalizing a commonsense model of motion (see Chapter 6).

4.3 THE NEED FOR A CLOSER LOOK AT THE NATURE OF MENTAL REPRESENTATIONS IN DYNAMICS

Both Guidoni (1985) and Hewson (1985) have taken the case of dynamics to raise issues about the nature of more generalised thinking schemes. Although both were concerned with the problem of promoting conceptual change in students' thinking they express very different views about the structure of commonsense knowledge. Guidoni supports diSessa's position, believing that the backbone of natural thinking is made up of such prototypes as:

i. A spring.

ii. Falling.

iii. A trigger.

Guidoni's ideas make more explicit than does diSessa how reasoning with prototypes could be involved in conceptual change. He suggests that these prototypes "have the task of stabilizing and making coherent our cognitive approach or to (way-of-looking-at) a given context". He also compares thinking with prototypes to analogical reasoning.

Hewson, on the other hand, argues that before a person is prepared to trust, react to or depend on knowledge, the knowledge must meet certain criteria. He suggests that these are:-

1. Internal consistency.

2. Generalizability.

Hewson comments upon the fact that in the area of dynamics people do not spontaneously generalize from experience to a Newtonion view and for him the interesting question is whether this is due to a failure to generalize or to some other cause. He proposes that it is through the construction and testing of models of thinking that these types of questions can be answered.

4.4 BUILDING A MODEL OF THINKING IN DYNAMICS

4.4.1 What is a model?

What features should a model of thinking contain? How is a model different from a number of descriptive generalisations chosen to represent the empirical data? The strength of a model or theory lies not just in its ability to describe knowledge in a certain domain but in its ability to illustrate the way in which that knowledge is arranged. An important methodological advantage of building a model is that it is open to test. The essential preliminary questions are:-

1. What elements can be used to describe the knowledge?

2. What is to be meant by the arrangement of the knowledge?

4.4.2 Models of commonsense understanding of motion

It is not surprising that there are not many models of "everyday" thinking in dynamics which are available for testing. There is however another discipline, apart from science education, which has been interested in how things move in an "everyday" sense, namely Artificial Intelligence. It was the influence of Hayes Naive Physics Manifesto (1979) which led to the development of Ogborn's (1985) theory of commonsense understanding of motion. These two models are described below.

4.4.2.1 Hayes' ideas about "everyday knowledge" of motion

Hayes wished to devise a computer program which could reason about the world in a natural way and chose to attempt to construct a formalisation of "everyday knowledge" in the physical world. Hayes suggested that many of our intuitive ideas about motion are derived from what it feels like when we move things for ourselves; including such activities as pushing, pulling, lifting, etc.

The elements he used to describe motion were the five ways in which motion could be initiated. These were:-

i. Falling

ii. Pulling or pushing

iii. Moving by itself

iv. Sliding

v. Rolling

He also made a distinction between movement that requires effort such as throwing a ball, and events which do not require effort and can just happen, such as an object falling.

Hayes used mainly predicate logic, in a computable form, for his formalisation. He selected two distinct ways of describing motion. These were by:-

a. Displacement, where there is a change in position of the object, and

b. Trajection, where the object follows a pre-determined path.

4.4.2.2 A synopsis of Ogborn's sketch for a model of commonsense ideas about motion

Ogborn (1985) drew on and added to Hayes's ideas. The theory set out to explain why particular conceptions of motion arise rather than others in our everyday understanding of motion. It is proposed (following Piaget) that the origins of these ideas could have been unconsciously achieved before the development of language and are derived from internalised action schemes.

In this first formulation of the theory there were four basic concepts used to describe motion.

Two of these related terms are **support** and **falling**. Falling is considered as a natural motion, since a cause is not required for it to continue. A support needs strength or effort (or both). The ground is the ultimate support and cannot break, whereas water or air can provide partial support.

The model also suggests that movement is conceptualised as taking place either on the ground or in the air above the ground, since all objects need some type of support unless they are falling. It suggests also that motions which travel in the vertical direction should be distinguished from those along the horizontal direction.

The two other basic concepts are **change of place** and **path**. The kinds of motion which can be distinguished by change of place are objects which are passed or pushed such as a plate or a pram while objects which are moving alone (such as a ball thrown in the air) can be located by their path and not the place where they happen to be at any instant.

The model proposes that the world is viewed filled with stationary objects which require a force to set them in motion, all motion apart from falling requiring effort. Perpetual motion is not possible because these forces eventually wear away or run out.

Since falling is seen as a natural motion, gravity is not considered as part of the basic theory but as a later refinement which is incorporated into the basic scheme as a rationalisation of free fall. A "law" of falling states "that having started to fall, things fall more rapidly the higher up and the heavier they are".

Motions can be distinguished by their source of effort. Three possible sources are postulated by the theory:-

i. Effort of another agent on the object

ii. Effort generated by the object

iii. Effort of the present motion of the object.

The structure of the model generates some interesting points about the nature and content of such models. At this stage the model is still in a generalised descriptive form. It is not as yet formalised, so the arrangement and relationship of the primitive elements is not totally clear. However motions can be determined from the type of support and effort that initiate them. One important objection to the model as it appears in this form (other versions are described in sections 6.2.1 and 12.3) is that it only describes the motion of single objects moving alone or together, which is more reminiscent of a Newtonian description of motion rather than a commonsense one, where objects are often found together and form part of one another. The model also neglects to mention the role of stopping forces, such as impacts, in a commonsense undertanding of how motion ceases.

4.4.2.3 Discussion of the model

Are there any other features from everyday experience that need to be considered? A list of logical opposites spring to mind:-

i. Up and down

ii. To and from

iii. Fast and slow.

Should the model have something more to say about these notions? Are they distinctions which should be included and would be found if the model was subjected to empirical test? Although the model states that ideas about motion are formed from early actions, this mechanism is not made explicit. The model also fails to mention any distinction between movements of animate and inanimate things. Piaget suggests that the young child's world is full of living forces and that movement is conceived in terms of "life and will, activity and spontaneity".

Piaget concluded that:-

1. Young children confine the use of force to bodies that move by themselves.

2. Force is described as activity/motion in general but is particularly associated with useful activity.

3. Force arises out of the actions of carrying and being carried.

4. The notion "strong" indicates a capacity for movement.

Finally, should such a model have something to say about the role of language? As Wartofsky (1968) suggests: "Our culturally inherited ways of talking about motion form part of that complex of perceiving and judging which shapes our experience to our thought as much as it exhibits the way in which our thought has been shaped by our experience". It is only through testing the model that the issues raised above about the structure and content of a commonsense understanding of motion can be addressed.

4.5 TESTING THE MODEL

Ogborn's selection of the specific primitives of SUPPORT, EFFORT, PLACE and PATH, exposes the model to test. These primitives should be found at the root of many explanations and justifications of motion and should appear relatively independently of context, if the model is generalizable and internally consistent.

The model not only makes predictions about the causes of motion but also predicts which types of motions are reasonable and possible and distinguishes these from crazy or impossible movements. Comic strip characters for example can run off a cliff top and continue to run in mid air before they eventually fall to the ground. This is an impossible action in real life because, as the model suggests, as soon as an object loses its support it falls to the ground. However, the cartoon joke works because the model sees birds as providing support through their own effort and there is the possibility that running in mid-air might provide enough support for the man but in fact this method of support does not work and the man falls to the ground.

The theoretical account provides a good general framework with which to examine commonsense ideas about motion. It allows a number of reasonably sharply posed questions to be asked about the content of the model and about the methodology which could be used to test the model.

1a. Are these the right primitives for a model of this nature?
The model gives different motions similar explanations, for example running is similar to flying in that they both use internal effort. Do people view these motions in this way?

1b. Are there other terms which are not mentioned by the model such as animacy, speed and types of stopping forces?

1c. Will such commonsense explanations be found across a wide age range of subjects?

2a. What sort of exploratory tool could be used to discover responses not anticipated by the model?

2b. The model's primitives form part of a tacit understanding. What is the best way to probe such tacit knowledge?

2c. Since the model is about understanding motion in a commonsense way then everyday type motions should be used for any investigatory study. In what form should these motions be presented to the subjects?

An interview approach suggests itself as a first step towards answering the above questions. Since an apriori theoretical position is being tested the questioner should have a clear idea of the questions to ask and of how to phrase them, but this format also allows enough flexibility for some questions to be determined by the subjects' answers. In this way provision is made for the subject to give unexpected answers, and further questioning can proceed to expose areas of thinking unanticipated by the model.

A preliminary testing of the model ought then to try to answer the following questions.

1. Are the main primitives of the model present in subjects' explanations of motion?

2. Are there any important pieces of the model missing?

3. Do the ideas predicted by the model appear across a wide age range of subjects?

Two different methods were used in the preliminary testing of the model. These were -

1. An interview and

2. A repertory grid study.

The use of these two methods is discussed in chapter 5. The results of the investigations allow one to address the questions raised above. The importance of this type of empirical data is that it is derived from the testing of a strong theoretical position:

> "One goal of all theory construction (and its testing)
> is the discovery of the deeper reality underlying appearance".
>
> (Carey 1985)

5. PRELIMINARY EMPIRICAL WORK ON STUDYING A COMMONSENSE MODEL

This chapter is in four sections. The **Introduction** describes reasons for choosing two different methodologies for the preliminary testing of a commonsense model of dynamics. The second section, **Investigating a commonsense model of motion with 11 - 14 year olds with an interview study,** not only gives an account of the results obtained from this study but also comments upon the usefulness of the methodology. The third part, **Investigating a commonsense model of motion using a repertory grid technique**, discusses the repertory grid technique and its contribution to the testing of children's commonsense understandings of dynamics. The final section, **Comparison of Repertory Grids and interview techniques to study commonsense understanding of dynamics**, contrasts the two methodologies as tools for probing tacit knowledge.

5.1 INTRODUCTION

The last chapter argued for the need for models of thinking in dynamics and discussed Ogborn's proposal (1985) for "understanding students' understandings of motion". This chapter reports pilot work on testing this proposal with two different methodologies to see:-

1. How well the theoretical position survived the testing.

2. Whether there are areas of children's thinking about motion which have not been addressed by the model.

The first pilot study used a clinical interview technique with a small group of 11 - 14 year olds. It follows from a previous investigation undertaken with a group of 14-18 year olds (Whitelock 1985), and the present findings are compared with this study, later in the chapter. This methodology was originally developed by Bliss (1984). The approach adopted was to conduct a number of individual interviews focused around a series of events illustrated in children's comics. These were chosen because they provided pictures which enabled the subjects to discuss "taken for granted" notions about every day movement.

A second group of interviews with 11 - 14 year olds was undertaken because it was considered important to talk to a number of younger children who had studied very little physics. This additional data would then provide a more complete picture of pupils' naive notions about dynamics in the secondary school age range. It would therefore be possible by comparing the results from the two age groups to see if commonsense understanding of motion changes with school science teaching and to identify any ideas which are more permanent than others.

The second empirical study reported here was conducted to experiment with a repertory grid technique, to see how well it could be used to investigate ideas about motion, particularly because it might allow a more systematic and extensive testing of the model.

5.2 INVESTIGATING A COMMONSENSE MODEL OF MOTION WITH 11-14 YEAR OLDS WITH AN INTERVIEW STUDY

5.2.1 Description of pupils interviewed

A small number of in depth interviews were carried out with a group of 11 - 14 year old pupils who had experienced different types of science instruction. The first and second year pupils were following a combined science course consisting of five lessons per week while the third year pupils attended separate Physics, Chemistry and Biology classes. (A total of six lessons per week). See Table 5.1 below.

Table 5.1: Description of science courses studied by the pupils who were interviewed

AGE	NAME OF PUPIL AND SCIENCE COURSE FOLLOWED	
11-12 years	S.P. H.M	First year Combined Science
12-13 years	K.D. A.W.	Second year Combined Science
13-14 years	M.L. D.J.	Separate Biology,Chemistry and Physics courses followed (All compulsory)

5.2.2 Methodology

The subjects were given four differerent comic strips taken from the following popular comics - The Beano, Beezer, Dandy and Topper. The interview material, i.e. the comics, was selected because characters from comic strips can be involved in a lot of action which is often fantastic or ridiculous and the movements illustrated are often parodies of more natural actions. In this way it was possible to test ideas expressed in the model without teaching them or suggesting any terms of the model itself. In addition, since comics are read by many younger children, their characters need very little introduction and are remembered by older pupils and even adults. The strips chosen described the adventures of the cartoon characters - Beryl the Peril, Ginger, Fred the Flop and Plug. (Copies to be found in appendix I). These characters were selected because their activities displayed a large number of different types of movement per cartoon strip.

The subjects were first asked to describe what was happening in each of the comic strips and then questioned about the feasibility of the actions of these cartoon characters in real life. They were also required to elaborate upon their explanations; for example, when a pupil suggested that an object would need more force to move it in the way depicted in the comic strip, he/she was requested to tell the interviewer more about the force mentioned.

5.2.3 Results

Analysis of transcripts

All the interviews were tape recorded and the subsequent transcriptions were analysed by noting the frequency of responses described by an apriori category system as previously used by Whitelock (1985). This category system was constructed to see if the main premises described by the model were used by subjects in their everyday explanations of motion. It was designed to see what sorts of ideas about the effort or force required for motion were actually used by the children. Did they utilize the notion of place and path of motion in their explanations? Were ideas about support and falling used systematically and was gravity omitted from such explanations? Other ideas not included in the model such as the nature of materials, stopping motions and the notion of intention were also included in the category system to see if they would be offered as explanation of everyday movement. The analysis was therefore devised to check the completeness and correctness of the theoretical model.

Table 5.2: Frequency of anticipated responses found in each category/comic strip

The frequency of anticipated responses found in each category/comic strip is illustrated by table 5.2. By anticipated responses are meant those which fitted the category system.

CATEGORY	FREQUENCY OF CATEGORY (FOUND IN COMIC STRIPS)				
	Comic Strip Ginger	Comic Strip Fred	Comic Strip Plug	Comic Strip Beryl	Total Frequency
1. SUPPORT & FALLING					
a. General notion of support	3		2		5
b. Strength of support	3		2		5
c. Partial support (air)	2		5	2	9
d. Falling (loss ofsupport)	1		3		9
e. Things fall faster the higher up they are or the heavier they are	6	1	5		12
TOTAL	15	1	17	2	35
2. MOTION					
a. Requires effort (if no gravity)	8	3			11
b. Place	2				2
c. Path	2				2
d. Effort needed larger - the larger the object etc.	6		2	1	9
TOTAL	18	3	2	1	24
3. FORCES					
a. Force as energy					0
b. Force as effort	2			1	3
c. Force creates motion	3	1	1	1	6
d. Force used up in keeping things going	7		2	4	13
TOTAL	12	1	3	6	25
4. GRAVITY					
a. Force pulling down	12		7	1	20
b. Used up in keeping things down	0				0
c. Gravity makes thingsgo farther and makes speed falling	6				6
TOTAL	18	0	7	1	26
5. STOPPING MOTION					
a. Impact stops motion				4	4
b. Running out ofenergy /force	2			1	3
c. Impact can hurt	6		2		8
d. Friction can stop or hinder motion					0
TOTAL	8	0	2	5	15
6. NOTION OF INTENTION	1	0	2	0	3
7. MATERIALS					
a. Strength	5	8	4	5	17
b. Type/Name ofsubstance from which the material is made	5	10	1	2	18
TOTAL	10	18	5	7	35

5.2.4 Were the major components of the model present as judged from the number of anticipated responses recorded from the pupil interviews?

The major components of a commonsense understanding of motion were present in the pupil responses. They perceived falling as a motion which occurred through lack of support. The support needed to be strong and made of the correct material otherwise it would break and the object it was supporting would fall. Some subjects emphasised the fact that adequate support needed to be beneath an object, as with brackets below shelves, more air under the wings of a bird and the need for air molecules to be stacked one on top of the other. Objects underneath provide support for those above but the question of the ultimate support remained unanswered. The theory proposes that the ground should be seen as the ultimate support (see 4.4.2.2).

Subjects reasoned that lighter objects fall more slowly than heavier ones, but that the latter's descent can be slowed down if the air can be gathered together in some way to provide a support. Subjects used this type of explanation when describing the function of a parachute. However, when they were asked to explain what caused the parachute's eventual landing, if the air was keeping it up, they realised they had met a contradiction in their reasoning. Some pupils then suggested that during the descent the air had somehow left the parachute while others felt the air could not simultaneously exhibit the two properties of holding something up while also letting it fall and used the notion of gravity to explain the parachute's eventual landing.

The model of commonsense ideas suggests that gravity is an optional extra to the core notion of falling which is described as a motion caused through a lack of support. Ideas about gravity should therefore be adjusted to fit in with the pupils' central expectations about falling. This study suggests that children do not need to explain falling in terms of gravity and agrees with the model's proposition that this notion is not a core concept of commonsense understanding. For example when explaining the descent of a person in a parachute Howard (11 years) explains that air is an important factor in preventing falling because with his way of thinking the air provides a source of support and only a lack of support is needed to cause falling. The notion of gravity is an unnecessary factor:

"Well if you want to go up you need to have the air, you have to capture the air to go up but if you're going down you have to sort of push it away".

The subjects agreed that all other types of motion apart from falling required an effort of some sort. Terms like "force" and "effort" were often used interchangeably. Their explanations suggest that forces are needed to create and sustain motion but that these forces or effort have to "run out" or disappear for the motion to stop. This can occur with impacts which suddenly stop motion. However, some impacts can create more force and thus further motion as in re-bounding. The model also suggests that effort can be used to change the path of an object including stopping and starting it, while motion using the effort of the motion will have a path of predetermined shape. Both these ideas were expressed by the pupils during the course of the interviews.

A persistent notion throughout the age range was that all motion apart from falling needed a force to start it. The 11 - 14 year olds experienced greater difficulty than the 14 - 18 year olds in describing the concept of "Force" as a generalised term which included ideas of effort and energy. They clearly stated that humans provided some source of "go" to make a ball move and that this "go" wore away as the motion progressed. They more readily used the idea of pressure to describe the push of things e.g. gravity pushes things down so it exerts a pressure. "I put pressure on the ball to make it move" etc. Pressure was used in a commonsense way and not applied in its scientific form. However the 11-14 year olds clearly expressed the idea that an increase in the speed of a motion will increase its force e.g. Fred had more chance of breaking down the door with his battering ram if he ran as fast as he could with it towards the door than if he walked with it.

The two basic notions of support and falling were used by all the pupils. They agreed that objects need support and without support will fall. However,whether the ground is seen as the ultimate support has not been fully investigated. The pupils' responses seem to suggest that it is viewed as the only type of natural and non-problematic support.

5.2.5 How well can the model account for what each pupil said?

Introduction

This section focusses on the responses recorded from the pupil interviews which were unanticipated and could not be directly coded into the category system by the model and category scheme. As there is a problem of interpretation of children's responses in terms of the theoretical premises with these particular examples they are looked at in more detail not only to investigate the completeness of the model but to assess the appropriateness of this technique as a probe for testing a model of commonsense thinking.

The following example illustrates the problem of interpretation of pupil responses. Stuart (11 years) confounds the notion of force and pressure. He says himself that it is a difficult concept to talk about.

I. So hitting with pressure is important?

P. Yes.

I. Can you explain to me again what pressure is, I am not quite sure?

P. It's like, well it's hard to explain isn't it, more than the normal pressure it's at because it's not really any pressure at all really. But if you get push against something hard that's pressurising it, putting pressure on it.

The commonsense model uses the blanket term of EFFORT to describe the "go" of things unless they are falling and the analyst has to decide whether thepupil's explanations in terms of force or pressure are used in the same way as EFFORT in the theory or are being applied in some other sense.

Discussion of unanticipated responses

i) Forces

a) Heat as a lifting force

The notion of energy is not used synonomously with the concept of force by the 11-14 year olds. However, Howard (11 years) does mention that heat provides a force - a pushing force.

I. Yes. I mean just here on earth, if you want something to stay up in the air what do you have to do, can you do that?

P. Make it lighter than air.

I. Lighter than air. Is there anything lighter than air?

P. Air balloons stay up with hot air in.

I. Yes but are they lighter than air?

P. Not really, no.

I. So how do they work then?

P. Well it must be the heat pushing them upwards.

I. So what would the heat do? It must be something to do with the heat, but what does the heat do?

P. Well heat goes upwards.

This is an example which could not be coded in the category system, and is not mentioned by the commonsense model.

b. Increasing a force

The original version of the commonsense model of motion said nothing about how a force can be increased. What intuitive ideas do pupils have about the factors which increase a force?

Howard realised that if you increase the mass you can increase the force since heavier things dropped on a ceiling will bring the ceiling down.

I. So anyway Dad gets really upset because she is being so naughty and she gets her pogo stick out and what does she do?

P. She bounces along upstairs and makes a hole in the roof.

I. Do you think that's feasible?

P. No I don't think it would.

I. Could she make the ceiling come down?

P. Yes if she had a really heavy thing.

This example illustrates an increase in heaviness associated with an increase of force and subjects also associate increase in speed with a bigger force. However, both variables are not used together. The chosen form of explanation appears to be context dependent and suggests the factor that is perceived to have the greatest influence in each situation. This raises the important question of how pupils decide what is important, and what sort of rule system they use.

ii) Gravity

Gravity was used less frequently by the 11 - 14 year olds who had not received any formal science teaching about gravity and motion, than in the previous study with 14 - 16 year olds, in keeping with the model's predictions. An interesting additional idea appeared about the **usefulness** of gravity. Subjects suggested that it keeps objects in place and in the upright position. Karoline explains:

I. Can you imagine gravity in any way?

P. I think a lot of things would be a lot harder without gravity. I think we take it for you know, we expect it really, with staying on the ground and staying on the desks and that. But if we didn't have it things would be a lot harder because everything would be floating and you wouldn't be able to keep them down in anyway ....

P. I would say that its like an invisible force on the um, and it pulls you and its all sort of like near the ground and it pulls you down and keeps you up, it keeps you upright.

The younger pupils used the idea of gravity less often than the 14 16 year olds to explain falling, which fits withthe model's position that it is only an "optional extra" to the core of commonsense ideas.

iii) Impacts

The category was included to try to see what types of impacts were regarded as capable of preventing the continuation of a current motion i.e. what sort of situations stop movement. The subjects' responses fell into two groups. Some classified impacts as increasing the speed of a ball and causing a continuation of motion while others felt that the same impacts stopped motion.

The following excerpts illustrate these types of reasoning.

Karoline aged 12 years thought that an impact should increase the speed of a ball because a hard surface is better than a soft surface to bounce against. She sees the soft surface as absorbing the force.

P. I think it gets faster as it keeps hitting things.

I. What about going up here to Dad's head?

P. I don't think that's very fast because it's got quite a long way to jump up, so I don't think it's very fast, I don't think it would hurt very much.

I. So what would make the ball stop?

P. If it stopped hitting all these surfaces and that, making all this force come into it. If it was just left on its own and the force came out of it.

I. So hitting things gives balls more force?

P. I think so yes.

Darren aged 13 explains why he thought impacts decrease the speed of a ball.

P. It goes into the picture or the mirror and smashes that, then it falls onto the flower pot and knocks it over then it hits a glass of water or something and knocks it over onto her dad's trouser and hits her dad on the head.

And later -

I. It would just stop would it?

P. It would fall down and it wouldn't bounce as high as it got on there.

I. Why's that? Why do you think it wouldn't bounce up so high?

P. Because the gravity is pushing it down so everytime it bounces a little bit lower than the last time but this one bounces higher sometimes.

It is interesting to note that both these accounts preserve one of the basic premises of the model that all things need a force to move them and that during the motion this force will wear away unless it receives some more force.

Two different views exist about the nature of impacts with a bouncing ball which can be summarised as follows:-

1. A person provides a force on a ball and if the ball hits a hard surface the surface can enhance the force on the ball or prevent the loss of force from it. If the surface is soft it will absorb the force. The generation of these types of explanations emphasises the material and type of surface which the ball hits and neglects the subsequent direction of motion.

2. However another view exists about impacts, that every time a ball hits a surface it loses some of its force.

5.2.6 Model and data: match or mismatch?

One of the primary objectives of the study was to elicit pupils' descriptions and explanations of motions and to determine whether the propositions of the commonsense model were reflected intheir responses. It appears that many of the fundamental notions of the model are used across the secondary school age range. However, only a restricted number of situations were looked at in this work and so the research needs to be extended to a wider range of instances comparing and contrasting many different types of motion. In addition, the sample was very small.

There are some interesting differences in the level of explanation obtained from the different ages tested. The older pupils' descriptions of motion emphasised more general features and they tended not to assess the particular features of a situation. They called less frequently upon the type of material to explain the notion of support. (A fuller description of the results obtained from the whole secondary age range tested is reported by Bliss, Ogborn and Whitelock (1989) and is found in Appendix XI). The model suggests that gravity is an optional extra; one would expect its use to be seen more frequently with the older pupils, and this is the case. Energy is a term used by the older subjects instead of force. These latter observations could well be the product of further exposure to more scientific notions which then blend into the commonsense understandings.

5.2.7 Methodological Comments

The advantage of this methodology was its flexibility as an exploratory tool. Pupils' ideas could be explored as they were spontaneously generated and the discussions which elaborated upon features illustrated in the cartoon strips in terms of real life situations gave some valuable insights into the children's ways of thinking about motion. The model describes its premises in the form of generalisations which people should have generated in order to understand motion. The use of these generalisations was more difficult to assess with this methodology since only a restricted number of instances were investigated.

This technique allowed the differences in pupils' explanations to be compared with the age group tested and although this study reveals,in contrast to earlier work (Whitelock 1985), that the younger pupils did not readily generalise, it does seem that the primitives of the model i.e. support and effort, can be found at the root of children's explanations. The methodology gave a further insight into children's ideas about gravity and impacts with the interesting observation that one of the basic premises of the model was preserved during the discussion about impacts, namely that motion needs a force, which can be lost. Although some of the technique's shortcomings have been discussed, this methodology proved to be a good first probe for elicting children's tacit understanding of motion.

5.3 INVESTIGATING A MODEL OF COMMONSENSE IDEAS ABOUT MOTION USING A REPERTORY GRID TECHNIQUE

5.3.1 Introduction

The purpose of this further piece of pilot work was not only to explore the use of another technique for probing pupils' tacit understanding of motion but also to provide a more systematic testing of the model. The information was collected to aid the formalisation of commonsense ideas about motion and to guide the choice of an investigatory tool for the main study.

5.3.2 Methodology

The repertory grid technique is derived from Kelly's (1955) personal construct theory. The theory runs counter to the behaviourist views of its time and suggests that man is actively engaged in making sense of the world in which he lives. The metaphor of man as a "personal scientist" is used to describe the activities in which the individual is engaged, such as testing hypotheses and evaluating experimental evidence, in order not only to understand the individual's environment but to predict and control events in it.

The theory proposes that everyone has a certain number of constructs by which they evaluate the phenomena that constitute their own world. These phenomena relate to elements such as people, events, objects or even ideas. Kelly suggests that constructs can be defined in terms of bipolar adjectives or phrases. An example of a bipolar construct elicited in the present study would be "something moving an object" versus "the object moves on its own".

Several variations of the repertory grid have been developed and used in different areas of research since Kelly's original 'Role construct grid test' and it is the flexibility of the technique which has made it an attractive tool for counselling, psychiatric work, and more recently for educational research. Kelly himself suggested that the grid was merely a means of communication through conversation to try and understand how a person thinks and feels about a particular topic through a set of constructs.

Kelly'sposition, as someone primarily concerned with individual therapy, was that both elements and constructs should be elicited from the individual. However in his theory he does argue that people do have similar ideas and areas of agreement in their understanding of everyday life. He describes these overlaps of ideas as the commonality of constructs. The model of commonsense ideas about motion suggests that a framework of notions of Effort and Support are used to make sense of motion and it follows that motions with similar types of Effort or Support should be grouped together and be seen as similar to one another.

The repertory grid technique can be used in one of three ways to study a persons' understanding of any universe of discourse:-

a. Elements and constructs can be elicited from the individual.

b. The elements are given while the constructs are elicited.

c. Both elements and constructs are given and the subject is left to match them together.

The above variations lend themselves to different types of problems:

Case (a) lends itself to individual diagnosis, and to such questions as how well a person understands or makes sense of a particular situation. It is suited to exploratory work and does not require the researcher to declare any strong hypotheses prior to its administration.

In case (b) the methodology is guided to some extent by a theoretical position through the selection of elements. This approach is appropriate for testing an apriori theoretical position without revealing it to the subject. It allows areas of common understanding to be identified.

The final variation of this technique is to give subjects both elements and constructs. This is a good method if the researcher wishes to look at different patterns of perception in a framework already understood.

What variation would lend itself to the further testing of children's commonsense understanding of motion? Method (b) was chosen since constructs could be elicited from the pupils about how alike or unlike they perceived the causes of different motions to be. The pupils' constructs could then be matched with constructs predicted by the model and also to see whether there were some constructs used by the pupils which had been omitted by the theoretical account.

The elements were predetermined by the researcher and consisted of fourteen pictures of different motions (see Appendix II). These are shown in Table 5.3 below and represent the following groups of motions:-

a. Motions on the ground or in the air.

b. Falling motions.

c. Autonomous motions.

d. Motions where the source of effort was external.

In this way the elements provide a representative coverage of the area of investigation. The elements also needed to be familiar physical objects so that they could be construed by the subjects without difficulty. Fourteen elements were thought a sufficient number to be discussed in an hour and to provide an adequate number for analysis. Easterby-Smith (1980) in his discussion of the design of a grid recommends twelve elements as a satisfactory number and warns against the use of less than six or seven if any quantitative analysis is to be done.

Table 5.3: The elements chosen to depict different types of every day motions

Element	Motion depicted on card
E1	Bowls
E2	Beryl running
E3	Police car
E4	Footballer
E5	Beryl on pogostick
E6	Sliding
E7	Kite
E8	Aeroplane
E9	Man with battering ram
E10	Bird
E11	Arrow moving up
E12	Bouncing ball on head
E13	Arrow moving across
E14	Drainpipe snaps

Pictures of the elements used can be found in appendix II.

The constructs were generated by presenting each pupil with the pictures of the fourteen elements in the form of cards. They first looked at the motion of each card to see if they understood the action described in each picture. They were then told that the reason for the research was to investigate their ideas about why things move and were asked to pick out two cards which moved for a similiar reason and then one that was very different. They gave the reason for their choice and placed the remaining cards in one or other of the categories. Another category was also created for any motions which did not fit into the chosen construct. They were asked to repeat this exercise until no more constructs could be elicited. This is the classical approach to generating constructs, that is, to elicit them from triads of elements. This procedure tends to produce two contrasting poles for the construct, and not opposites. The difficulty with requesting "opposites" is that it often produces logical opposites rather than opposites in meaning. The maximum number of constructs obtained during the course of the interviews was twelve, the minimum being ten.

The whole interview was tape recorded and a grid completed for each pupil. A sample grid is illustrated in Figure 5.1 the others are found in Appendix III, and rates the elements with a numerical score per construct. The score is from one to five. A five point rating scale is shown below:

Not at all alike — Average — Very much alike

1 — 2 — 3 — 4 — 5

Bannister (1968) comments on the advantages of the rating form of the repertory grid and suggests that it offers the subject greater latitude in distinguishing between elements than that provided for in the original form proposed by Kelly.

5.3.3 Descriptions of pupils interviewed

Four sixth form pupils (average age 17 years) were interviewed. Two were arts 'A' Level students while the others were studying science 'A' Levels.

A further four pupils were in their first year of secondary education at a comprehensive school and had an average age of 11.5 years. This group followed a combined science course. As this was only a pilot study, in order to assess the suitability of the technique for eliciting commonsense ideas, the extremes of the secondary school age range were used.

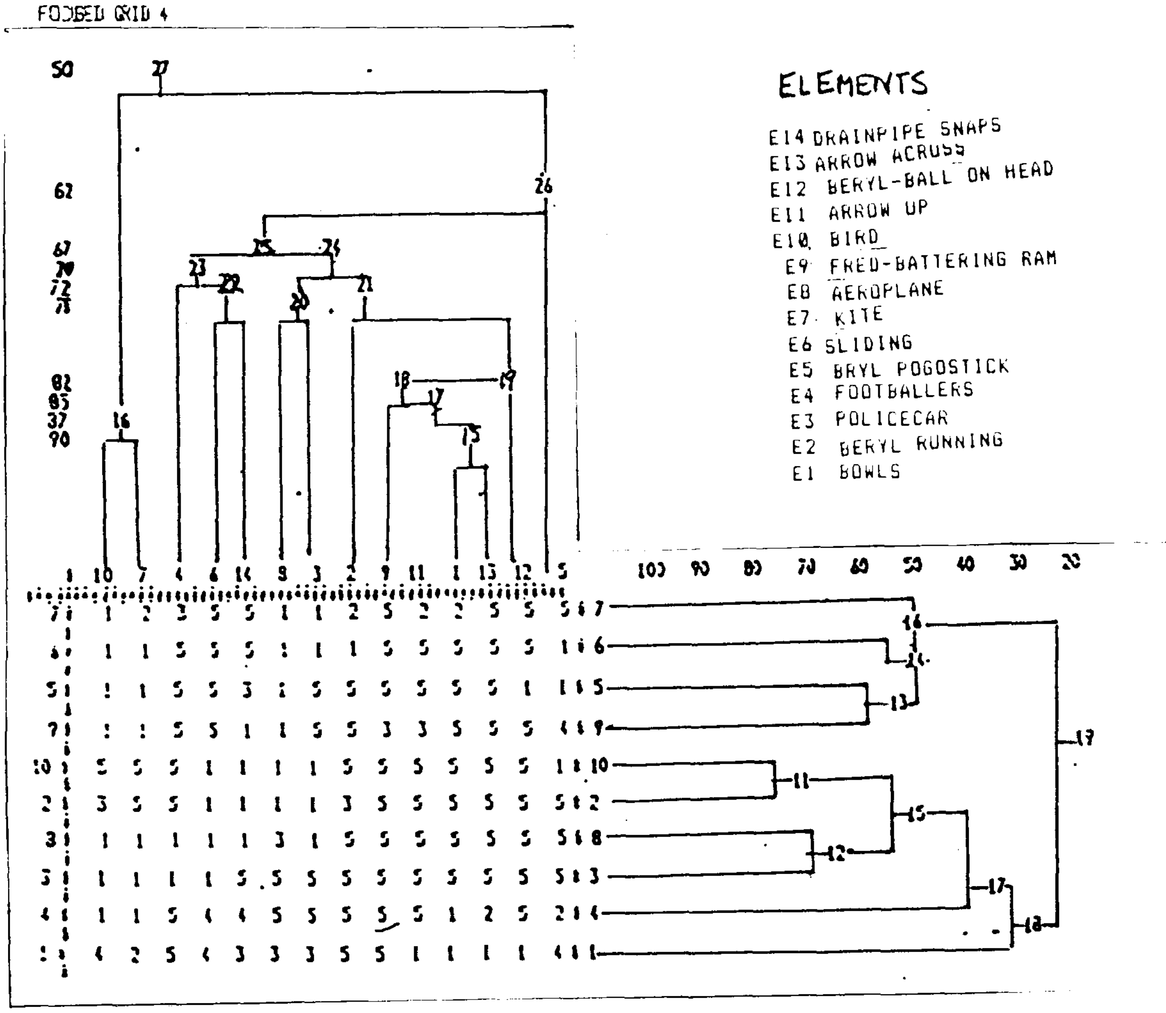
5.3.4. Looking for patterns of constructs in individual grids

The repertory grid technique was used not only to elicit tacit knowledge but also to see if the constructs used by each pupil and between pupils of different ages were those predicted by the theoretical model.

Figure 5.1 : Focused Repertory Grid

Name of Subject: 1st year

Number of Grid: 4



Constructs

1. Running - standing still
2. Person moving something - person being moved by something
3. Moving something because there is a reason - being taken by surprise
4. Moving fast - moving not so fast
5. Motion across - motion upward
6. Motion which hits something - motion which does not hit something
7. Gravity helps movement - gravity does not help
8. Person using a force to make something move - moving on its own
9. Movement on the ground - movement in the air
10. Movement in/on something - movement not in/on something

Constructs 7 and 10 reversed

(numbers at cluster nodes are merely labels for new nodes)

Table 5.4: Allotting Elements to Constructs using the Rating Form

An example grid of a 1st year pupil

Constructs	Elements 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Running/standing still	1	5	3	5	4	4	2	3	5	4	1	1	1	3
2. Person moving something/person being moved by something	5	3	1	5	5	1	5	1	5	3	5	5	5	1
3. Moving something because there is a reason/ being taken by surprise not intentional	5	5	5	1	5	1	1	5	5	1	5	5	5	5
4. Moving fast/moving not so fast	1	5	5	5	2	4	1	5	5	1	5	5	2	4
5. Motion across/motion up	5	5	5	5	1	5	1	1	5	1	5	1	5	3
6. Motion which hits something/motion which does not hit something	5	1	1	5	1	5	1	1	5	1	5	5	5	5
7. Gravity helps movement/ gravity does not help movement	4	4	5	3	1	1	4	5	1	5	4	1	1	1
8. Person using a force to make something move/moving on its own	5	5	1	1	5	1	1	3	5	1	5	5	5	1
9. Movement on the ground/ movement in the air	5	5	5	5	4	5	1	1	5	1	3	5	5	1
10. Movement in/on something/movement not in/on something	1	1	5	1	5	5	1	5	1	1	1	1	1	5

Code for elements in figure 1 above:

1. Bowls	8. Aeroplane
2. Beryl running	9. Fred/battering ram
3. Police car	10. Bird
4. Footballers crash	11. Arrow across
5. Beryl on pogostick	12. Beryl bouncing ball on head
6. Sliding on rug	13. Arrow up
7. Kite	14. Drainpipe snaps (Fred)

Each individual grid was analysed with the computer program FOCUS (Shaw and Thomas, 1978) to identify the relationship between the constructs for each subject. The FOCUS program looks for different patterns and identifies the major groupings of constructs in the repertory grid. It is based upon a cluster analysis where the strongest associations in the matrix are found and a series of hierarchical groups of constructs are then built. It sorts the constructs so that those which have the closest relationship are closest together in order. The original grid is therefore reorganised by the "relatedness" of constructs and elements.

In order to demonstrate how the main patterns of each grid are identified by the FOCUS program an example of a Focused grid of an 11 year old pupil, S. D. is discussed below. (See figure 1).

The program identified three clusters of constructs for S.D.'s grid, which are grouped in the following way:-

Cluster i. Contains the constructs 10, 2, 8 and 3

ii. Contains the constructs 9, 5, 7 and 7

while cluster iii. Includes only the constructs 4 and 1.

In the first cluster, the sub-cluster of constructs 10, 2, 8 and 3 have in common the notion of an agent acting on something or carrying something. Cluster two includes the constructs 9, 5, 6 and 7 which describe falling motions connected to ideas of gravity, along with up and down movement and motion which hits something. The third set of constructs which are only weakly linked i.e. at the 35% level, include ideas about the speed of motion.

There are similarities between the degree of relatedness of elements as perceived by the different age groups of pupils tested. Direction and source of effort of motion and differences between animate and inanimate motion were the main criteria used by the eleven year olds to distinguish motion, while the seventeen year old pupils added a further feature, of difference which separated motion taking place on the ground from that in the air.

5.3.5 The most common constructs elicited from the subjects

The FOCUSed grids helped to show how the individual pupils construed the given elements (see appendix III). To identify common trends, constructs with similar labels were grouped and FOCUSed together to discover how close they actually were in meaning. Table 5.4 summarises the constructs which were grouped in this way. It shows the frequency of constructs with similar labels, and investigates how close they are in meaning by looking at the similarity in their pattern of elements.

Two of the most frequently elicited constructs were concerned with the notions of SUPPORT and EFFORT. Both these ideas were predicted by the theoretical model. With respect to SUPPORT, subjects differentiated between motion taking place on the ground from movement in the air. They mentioned properties associated with travel in the air such as lightness. The wind was also considered to be a cause of motion. Movements were also contrasted by their source of effort and subjects not only discriminated between an internal and external force but also between animate and animate motion. The latter distinction had not previously been mentioned by the model. The third most frequently and closely linked distinction, again omitted from the theoretical account, concerned purposeful or deliberate motion as opposed to accidental or uncontrolled action. Sliding/slipping/falling were seen as examples of accidental movements.

Other constructs identified by this method were as follows:-

i. The direction of the motion - distinctions made betwee movement in the horizontal and vertical direction.

ii. Speed of motion.

iii. Impacts causing motion to stop. The seventeen year old pupils mentioned friction as a means of stopping movement.

iv. "Carry-type" motions i.e. objects which are moved in or on another object.

Table 5.5: Constructs with similar verbal labels FOCUSed together

GROUP NAME OF CONSTRUCTS	NUMBER OF CONSTRUCTS FOUND WITH SIMILAR VERBAL LABEL	% SIMILARITY IDENTIFIED BY FOCUS PROGRAM
1. Internal versus external force producing motion	7	4 at 55% all at 39%
2. Speed linked with shape of moving object	6	5 at 55% all at 30%
Shape aids motion/shape does not aid motion	4	Results suggest these were two separate groups of constructs concerned with speed of motion and shape of moving object
3. Movement in air versus movement on the ground	9	5 at 65% 7 at 50%
4. Wind assisted motion versus non wind assisted motion	11	7 at 60% 9 at 50%
5. Moves across versus moves up	7	4 at 60% all at 40%
6. Gravity and motion	5	4 at 60% all at 55%
7. Purposeful/deliberate motion versus accidental motion	7	6 at 55%
8. Purposeful motion linked with motions towards something versus motion away from something	10	6 at 55%
9. Controlled purposeful motion versus non-controlled motion	10	8 at 55%
10. Stopping motions versus continuous motion	5	2 at 85% 3 at 50%
11. Movement in or on something versus movement on its own	4	2 at 90% 3 at 50% all at 45%
12. Internal versus external force	10	8 at 50%
13. Light objects moveeasily versus heavy objects do not move easily	13	8 at 50%
14. Rolling versus bouncing motions	3	2 at 30% No real linkage
15. People moving versus people staying still	4	2 at 40% No real linkage
16. Motion needs a fuel versus motion does not need a fuel	3	2 at 20% No real linkage

5.3.6 What did the repertory grid technique reveal about the commonsense model of motion?

In order to assess what this methodology has revealed about the commonsense theory of motion, three questions need to be answered.

1. Are the major components of the model present?

2. Do any new ideas arise, which were not previously mentioned by the theoretical model?

3. Are some pieces of the model missing when this technique is used?

Let us now consider these questions:-

5.3.6.1 What were the most frequently elicited constructs which were predicted by the model?

The theoretical model predicted that motions should be distinguished by the type of effort used to produce them. The subjects responded in this way by separating motions produced by the object itself from those started by another object. Pupils also distinguished the difference between motions taking place on the ground or in the air, which is also a basic premise of the theory, concerned with the notion of SUPPORT.

5.3.6.2 Were any new constructs elicited which were not predicted by the model?

The activity of classifying elements with reference to two poles allowed new ideas which were not covered by the model to be revealed.

These were:-

i. Differences between animate and inanimate motion.

ii. Accidental/purposeful motion.

iii. Conditions for stopping motion.

iv. Speed of motion.

v. Bouncing/rolling motions seen as different to other motions.

5.3.6.3 What constructs as predicted by the model were not elicited from the pupils with this technique?

Falling motions were not seen as different to other motions in terms of lack of SUPPORT or EFFORT. The pupils gave some indication of difference but this was in terms of direction. They distinguished changes in motion between up and down. There was only one falling motion placed among the elements and that was a burgular falling from a broken drainpipe and this fact could explain a lack of classification of Falling motion.

There was no mention of objects moving due to the effort of the motion. The theoretical model suggests that effort is preserved within an object, once given by an agent. This effort sustains the object's independent motion until the effort is used-up or runs-out, e.g. as in a ball thrown into the air. The thrower gives the ball effort which is used up as it travels through the air. As soon as the effort is extinguished the ball drops or falls immediately to the ground. This omission could be due to the lack of examples whose motion could be explained in this way. Only four of the fourteen examples could be considered as moving in that manner.

The fact that certain constructs did not appear, poses an interesting problem. These omissions could be due to a methodological problem in the choice of elements or might be an indication that these constructs are not important features of a commonsense understanding of motion.

5.4 CONCLUSION

The Repertory Grid study formed a second phase of the preliminary testing of a commonsense model of motion and suggested that the major components of the model were present. The model's prediction that "motions have a preferred direction" and that motions can also be distinguished by their source of effort was given further support. However, any idea about the effort of the present motion of the object was not forthcoming in this investigation although it was found in the interview study.

The most important distinction not in the model was that of animate/inanimate motion. The other features such as rolling/bouncing, and speed of motion were less important findings. In order to see if these type of actions could be included in a basic set of commonsense actions, upon which all sets of motion could be based, the model needs to clarify the characteristics of different motions more fully. Ideas such as rolling and bouncing need to be considered since any commonsense theory of motion should predict the sort of motions which people naturally use in order to make comparisons.

The repertory grid methodology provided a suitable and useful technique for the exploration of pupils' commonsense understanding of motion. It may also provide a useful tool to promote a change in commonsense ideas. This methodology elicits the subjects' own personal constructs, which are then available for discussion. Areas where commonsense reasoning provides insufficient explanation may be made explicit, when the pupil might be more willing to 'take on board' a less naive and more scientific view of how the world works.

5.5 COMPARISON OF REPERTORY GRID AND INTERVIEW TECHNIQUES TO TEST COMMONSENSE UNDERSTANDING OF MOTION

The first methodology employed was the clinical interview and from this work a variety of notions were identified connected with movement. Similar ideas were found in all the pupils tested whose ages ranged from 11 to 17 years. Three kinds of EFFORT were discovered as necessary causes of motion. These were:-

i. Effort needed to initiate motion.

ii. Effort needed to maintain motion or used up in motion.

iii. Exchange of effort.

The pupils talked about the notion of support in terms of its strength or lack of it. The outcome of lack of support resulted in a motion commonly known as falling.

Other ideas of gravity and impact were mentioned. Gravity was described as a force that pulls things down or as something that is used in keeping things down. The strength of impacts was mentioned in terms of either the material of which the object was made or the speed of the moving object.

The interview study did not however identify certain constructs which the repertory grid technique revealed. These were differences between animate and inanimate motion, the identification of bouncing and rolling as classes of motion and ideas connected with the speed of the movement.

The repertory grid technique proved to be a successful means of exploring a model constructed of generalisations. The methodology required subjects to make such **generalisations** in order to classify the given elements in a very explicit manner. There is a disadvantage with this technique, in that it is not easy to probe ideas in depth if a large number of constructs for computer analysis are to be elicited within a reasonable time scale, since attention has to be sustained on the grid elicitation process. It is also difficult within the repertory grid interview format to follow up interesting or unusual feature as they arise.

Another way of testing a model with this technique would be to have both elements and constructs predetermined. Then more rigorous "across person" comparisons could be made and the commonality of ideas within the group more easily assessed. The interviewer could concentrate more completely upon the level of reasoning and the types of explanations used

Table 5.6: Comparison of Repertory Grid and interview techniques to study commonsense understanding of dynamics

	METHODOLOGIES	
FEATURE OF METHODOLOGY	**INTERVIEWS**	**REPERTORY GRIDS**
1. Appropriateness for phase in research.	Good first exploratory tool.	Provided more systematic testing of the theory.
2. Information obtained.	Notions of support. Three kinds of effort. Impact. Gravity. Not mentioned. Not mentioned. Not mentioned. Effort of the motion. Same ideas expressed throughout age range tested 11 - 16 years.	Motions in air or on ground. Only 2 present. Impact. Gravity Animate/Inanimate. Conditions for stopping. Bouncing and rolling motions. Not mentioned. As theory predicted many constructs were expressed by both 11 and 17 year olds but animacy emphasised more by 11 year olds.
3. How close did each technique come to the pupils' common-sense reasoning?	As fuller explanations given it is easier to check pupils' reasoning.	Although easy to check the classifications predicted by the model not so easy to confirm the reasoning.
4. Allows further exploration of interesting new features.	Yes	More difficult.
5. LABELS and meaning.	Easier to check labels used and meaning by further probing.	Need to be aware that similar construct means a similar construct label with a similar pattern.
6. Readily lends itself to statistical comparison of age groups.	Can be done with difficulty.	Yes.

to classify motions in a commonsense manner. However, the difficulty is then that subjects would be instructed in a "commonsense model of motion" by the process of investigation.

However both techniques suggest that the model's primitives of Effort and Support are used to explain different types of motions across the secondary age range, so that these primitives need to be preserved within any model. These two investigations offered different ways of probing a commonsense understanding of motion by seeing if subjects agreed with and replicated the terms of the model. The results of these studies informed the choice of research instrument for the main study as discussed in Chapter 7.

6. FORMALISING A MODEL OF COMMONSENSE UNDERSTANDING OF MOTION

The purpose of this chapter is to describe the formalisation of a model of commonsense thinking about motion. 6.1 **Towards a formal model of commonsense understanding of motion** discusses the role of causality. 6.2 **A causal model of motion** illustrates the construction of the causal model through a series of systemic networks. 6.3 **Conclusion** describes how the formalized model lends itself to testing.

6.1 TOWARDS A FORMAL MODEL OF COMMONSENSE UNDERSTANDING OF MOTION

In the interests of further clarification, and as a step towards further testing of the model, the construction of a FORMAL account of a commonsense understanding of motion suggested itself as an appropriate second stage of this research. Therefore Jon Ogborn, Joan Bliss and myself began to formulate the model of commonsense reasoning as a systemic network (Bliss, Monk and Ogborn (1983)) using the results of the preliminary studies as described in Chapter 5.

6.1.1 The role of causality in building a formal model of a commonsense understanding of motion

In order to build a formal version of the commonsense model of motion, it was important to look for some underlying pattern in the construction of the "primitive" abstractions and to explore the possibility of identifying a common framework which pupils might use to make sense of a world made up of objects which can be made to move in a number of different ways. As suggested in 4.4.1, it is not only the elements or primitives but also their **arrangement** that is required to define a model. Therefore, any commonsense model of motion needs to clearly explain the link between EFFORT and SUPPORT, and if possible to suggest how these notions could develop.

A model based on an analysis of causation seemed appropriate. A number of researchers suggest that an understanding of causality is central to our ability to deal successfully with the complex world in which we live. For example Michotte (1963) has proposed that we tend to seek causal explanations or impose causal interpretations on events in space and time regardless of their underlying relationships.

Bronowski (1969) also suggests that the idea of cause and effect has taken a powerful hold on our minds. He says:-

"We have the greatest difficulty in freeing ourselves from its compulsion, even when we are thinking through scientific problems with conscious care. And unconsciously, we fall back on it at every turn. This has become our natural way of looking at all problems".

According to Piaget (1928), one of the important steps in development is the ability to recognise cause and effect relationships. In his description of the sensori-motor period Piaget proposes that the notions of causality, object time and space are constructed through the child's action on and experience of the world and that causality appears in its most rudimentary form during this period. At the beginning, this understanding is limited to the most direct sorts of physical causality such as an infant dropping a toy from his high chair and causing it to fall, or pulling a string on a musical toy and causing it to play a tune.

Wartofsky (1968)in agreement with Piaget, proposes that one of the most basic notions that we have about causality is that of action. There are several features of action which immediately suggest themselves:-

i. Human action involves a feeling of effort.

ii. Action involves some motive or intention or something for which we need to give a reason.

iii. Actionis achieved by physical contact.

The implication is that causality and action are tightly interwoven from early experience. If this is correct then it is reasonable to expect ideas about causality and motion to be similarly linked.

6.1.1.1 A Philosophical approach to causality

Although causality presents itself as a "good glue" for our model of motion it is helpful to look briefly at the concept of causality itself before the details of a causal model of motion are discussed.

Philosophers have been wrestling with the problem of trying to find a definition of causality for centuries. One of their approaches has been to describe causality in terms of necessary and sufficient conditions. A sufficient condition is one whose presence guarantees that the outcome will occur, that is, a condition that can never be present if the outcome does not occur. For example, in a commonsense understanding of motion a lack of support is a sufficient condition for an object to fall. On the other hand a necessary condition for some outcome is one that must always be present for the outcome to be present. That is, a condition whose absence will prevent that outcome. An example of a necessary condition is when support is necessary for a PUSH or WALK type motion to take place. Just the presence of the ground or similar support does not ensure that these types of motion occur. However, we know that if a PUSH or WALK motion has happened then a support of some sort is present otherwise a FALLING motion would have occurred.

Another view of causality, which seems much closer to our everyday natural-language sense of the meaning of cause, proposes that a cause should be defined as an "incident or action which, in the presence of those conditions that usually prevail, make the difference to the occurrence or non-occurrence of the event". (Copi 1978). Schustack (1988) suggests that this definition "captures more of the psychological sense of cause". For example if eleven year olds are asked to classify pictures of different motions according to similar causes (as in the repertory grid study, see 5.3.2), subjects tended to group animate motions as similar because animate objects have control over their motion and not just because they have an internal source of motion. Real people walk about for a reason such as moving across a room to open a window or shut a door. There is some purpose to their action. However, moving for a reason or a purpose cannot strictly be considered as a necessary or a sufficient condition for a WALKING motion to take place, if the philosophical definition above is used.

There are other problems in applying the philosophical definitions of necessary and sufficient cause to people's normal causal reasoning. Schustack (1988) proposes that they neglect the "critical processes of generating or identifying candidate causes (causal hypotheses)".

An appreciation of a commonsense understanding of natural phenomena requires not only an analysis of sufficient or necessary conditions of cause but also more detailed information about the agent of cause. This understanding can then be compared to a scientific account of the world to see how it differs from it.

6.1.1.2 Views from the Alternative Conceptions literature about the role of causality in commonsense thinking

Driver, Guesne and Tiberghien (1985) edited a collection of papers describing secondary school children's ideas over a wide range of natural phenomena. Their editorial comment set the individual pieces of reported research within a general perspective, which included as a feature that children's everyday explanations of change follow a linear causal sequence, (see also section 2.5). Driver et al suggest:

"They (children) postulate a **cause** which produces a chain of **effects** as a time-dependent sequence. This tendency to think of explanations in terms of preferred directions in chains of events mean that pupils can have problems appreciating the symmetry in interactions between systems".

Andersson (1986) proposes that the alternative conceptions literature could be understood in a more unified manner if the findings were interpreted within a causal framework. He suggests that the common core of pupils' explanations of phenomena in such widely differing areas of science, as temperature, heat, electricity, optics and mechanics, is that of an "experiential gestalt" of causation. The idea of the experiential gestalt was taken from the work of Lakoff and Johnson (1980), in which they postulate that ideas of causality are deeply rooted in language as well as in early experience.

Andersson postulates that "we use the experiential gestalt of causality all the time to control our actions and to comprehend what is happening in the world around us". The main features of the gestalt are "an **agent** which directly with its own body or indirectly with the help of an **instrument**, affects an **object**. The introduction of the notion of instrument helps to describe a causal chain. An example Andersson uses is as follows:

"The child (agent) throws a snowball (instrument) to knock the cap (object) off his friend".

He suggests that in order to broaden the scope of the investigation and the analysis of children's alternative frameworks, this research needs to look at the notion of causality in conjunction with the content of students conceptions.

This discussion has briefly reviewed current opinion about the role of causality in commonsense reasoning and presented some of the arguments for proposing that the primitives of EFFORT and SUPPORT can be linked within a causal framework. In the following section the formalisation of the causal link is made explicit.

6.2 A CAUSAL MODEL OF MOTION

Causality suggests itself as the glue which holds the pieces or primitives of a "structured understanding of motion" together. These primitives have been identified as SUPPORT and EFFORT whose characteristic features were outlined in section 4.4.2.2.

The notions of support and effort are the central and most important primitives of the model. They are also the basic premises which distinguish this model from any other model and therefore any formalism chosen to present the model must be able to represent them and their connection with other ideas.

The formalism chosen was that of a systemic network since it could display a structure of categories revealing their interdependencies to any required level of delicacy. A systemic network should also produce a definable degree of difference between motions which can then be tested. It was hoped, in addition, that the formalism would also lend itself to a later translation into a Prolog program.

A causal model of motion is presented below. This is the version of the model developed prior to the design of the matching tasks (see Chapter 7). Since the collection of the empirical data ideas about the model have changed and another version is proposed in Chapter 12 and tested against the available data.

The first network (Figure 6.1), suggests that in order for any type of motion to take place there must be a cause, which can be circumstantial or be specific to the object.

Figure 6.1: A causal model of motion described by a Systemic Network

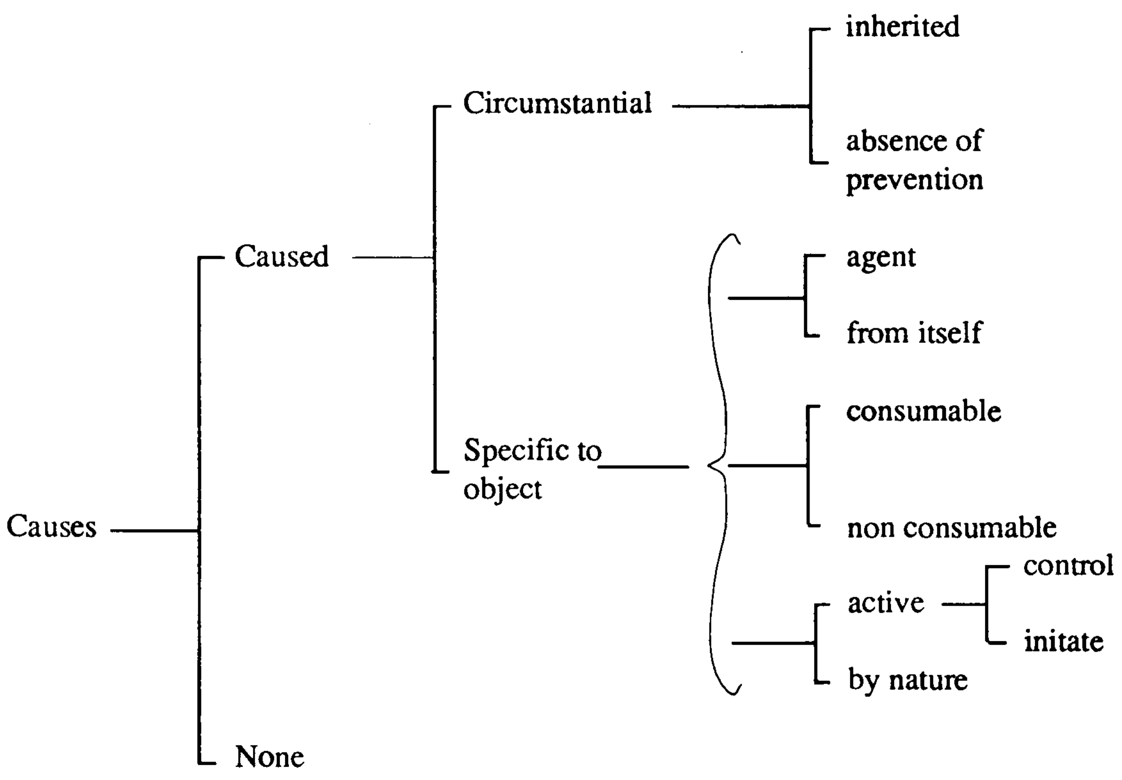


Figure 6.1 describes two types of circumstantial causes; **inherited and absence of prevention.** The former cause specifies how one object can be moved by inheriting its cause of

motion from another moving object; i.e. the cause is not specific to the object alone. An example of this type of motion is that of carried objects moving together, such as a person taking a cup and saucer to the sink. In real life some objects are always seen together and are found to move in groups and form part of one another. This new theoretical qualification answers one of the criticisms of the earlier version of the model (see 4.4.2.2) which only describes the motion of single objects found alone or together.

The other type of circumstantial cause is **Absence of prevention** which is a special type of causation where it is the nonexistence of a certain agent which would have prevented the motion if present, that is seen to be the cause of motion. This category allows a lack of support to act as a cause of movement, to account for **falling**. Objects are seen to fall when nothing supports them.

The other distinction on the second BAR of Figure 6.1 is a cause which is **specific to the object**. This is an overall category for entrance into a BRA in which there are three co-occurring sets of options.

i. Agent/from itself.

ii. Consumable/Non consumable.

iii. Active/by nature.

Agent causes occur where an event is seen to happen through the specific action of an agent on another object whereas "from itself" causes are cases seen as an pbject causing its own motion.

The **consumable/non consumable** distinction is used to describe the "power of causation" and differentiates between causes where this power is used up or is seen as a permanent attribute of the cause. For example an object can be supported through its own effort. e.g. a bird flying into the air. This effort is used up during the course of the action and so is classed as consumable, whereas a statue is supported on a pillar by the strength of the material in the pillar itself, which is a non-consumable cause.

The **Active/by nature** distinction differentiates between events which are said to happen naturally from those which are made to happen. An example of a **natural** cause is that of a ball falling. It will continue to travel unaided until it stops "naturally". This type of cause occurs when there is no intervention either from the objects themselves or the agents during the course of the event. If asked why a "natural type" action happened the response might be "because it happened".

The **active** option describes a type of intervention which is needed to inject some sort of activity into a situation or series of events to make things begin. This **activity** can just start things off as denoted by a further differentiation called **initiate**. An example of an **active initiate** motion is that of a person throwing a ball into the air. Whereas an **active control** type motion can be illustrated by the example of a person pushing a pram. Here the source of effort is external and applied continuously to the moving object.

The causal network of motion makes explicit the notion that all types of movement need some sort of cause. When a cause is absent then there is no motion and the status quo is maintained. The network acts as a template for a more formal description of the "primitive" abstractions of SUPPORT and EFFORT as shown below (figures 6.2 and 6.3).
The support network (figure 6.2) differs from the preliminary causal model (figure 6.1) in the following way:

i. It is a simpler description.
There are only two possible types of causes of support which are **by agent** and **from itself.**

ii. When a cause of support is absent the status quo is not maintained as regards to motion and falling occurs.

iii. The support network (Figure 6.2) omits certain distinctions made by the causal network (Figure 6.1). These are:

a. No consumable/non consumable distinction and

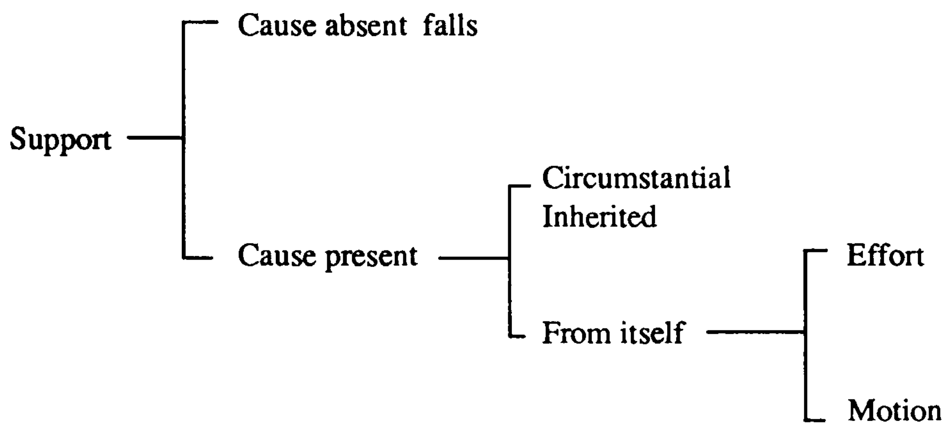
b. No active/by nature distinction.

iv. When support is given by the object itself it can be established in one of two ways:

a. through effort - ie a bird supports itself throughthe the effort of flying. (This is a consumable support).

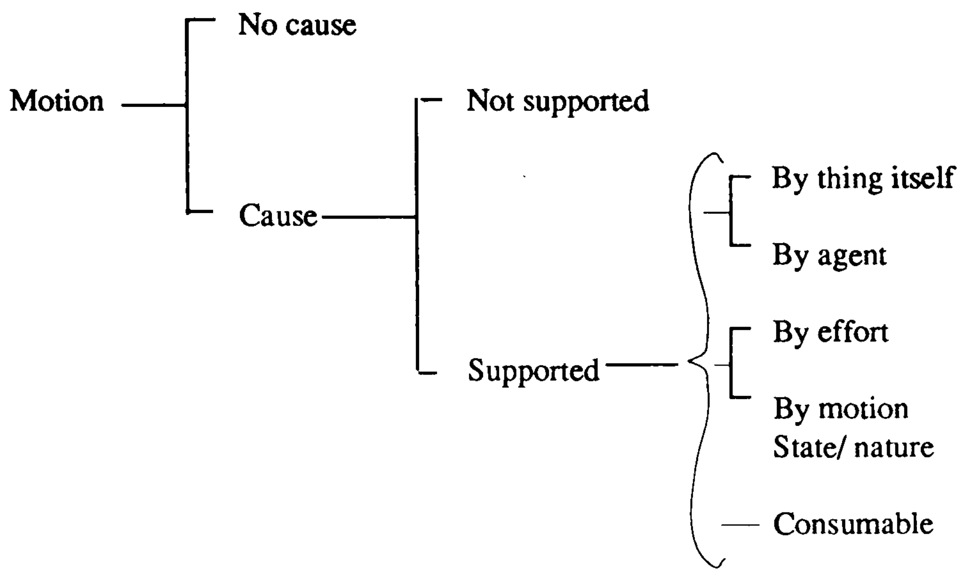
b. through motion - a ball remains in the air through its own motion before it falls to the ground.

Figure 6.2: Network for support



The motion network (figure 6.3) differs from the main causal model of motion (figure 6.1) in only one respect; the omission of a non consumable source of effort. The model thus asserts that it is impossible to have continuous motion (except falling) without using up effort.

Figure 6.3: Network for motion

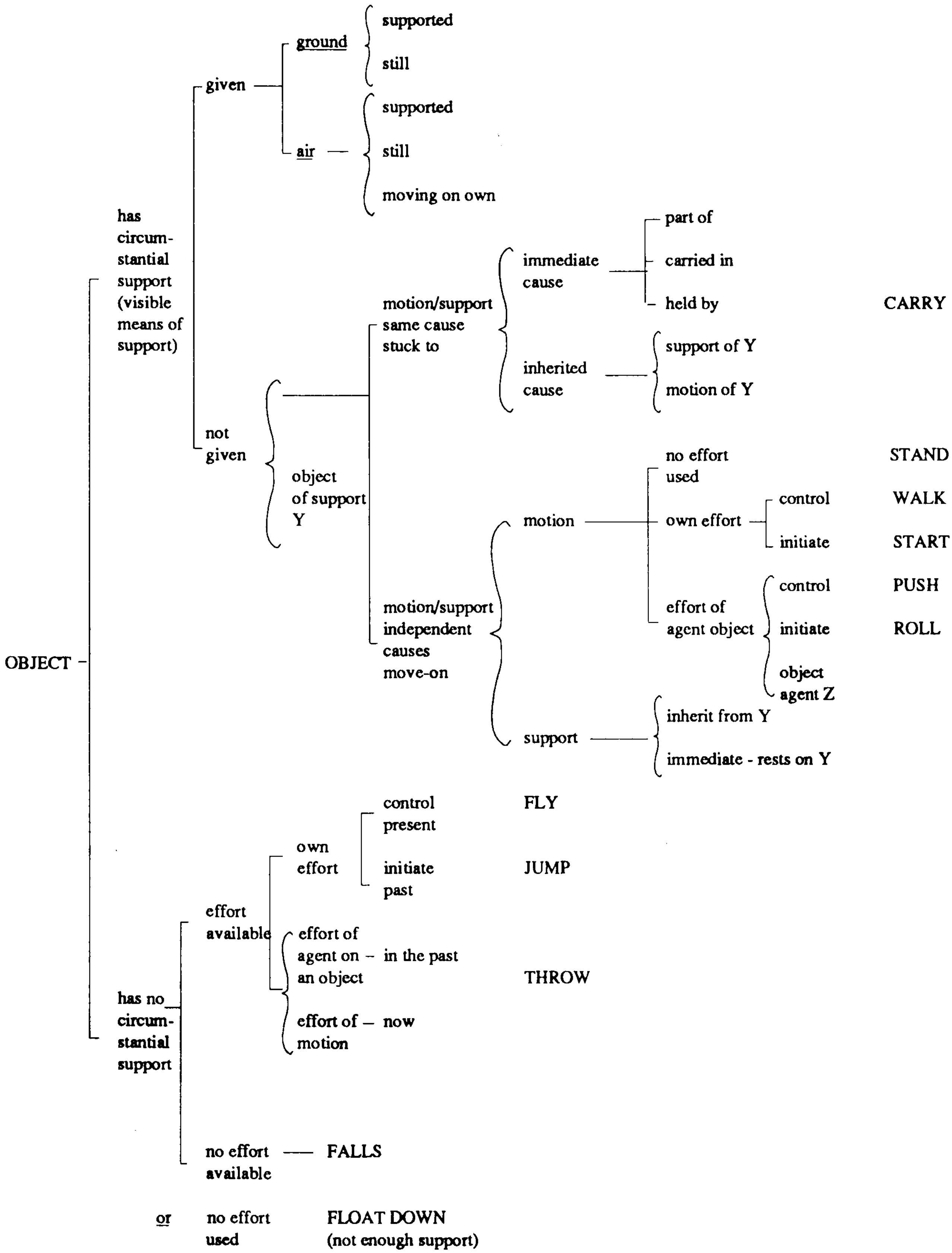


6.2.1 Model of a commonsense understanding of causes of motion as described by a systemic network

Since the theoretical model proposes that the two notions of support and effort are the essential ingredients of a commonsense understanding of motion the causal networks of support and effort were combined into one common network as shown in figure 6.4 below. It is this latter model with its predictions about everyday motions and their relationship to one another which provided the basis for the main investigation of this thesis. This final network describes the relationship between different types of support (i.e. the ground or a similar substitute, the air or self-support) **combined** with different sources of **effort** (essentially own effort or the effort of an external agent) which give rise to a number of basic cases of motion. These are the paradigm cases of the networks which are defined as "stereotypes". The stereotypical motions have a particular configuration of features and one testable aspect of the model is to see how well it actually characterises the differences between the stereotypes.

The network paradigms define the "stereotypes". These will be used in later empirical work for which picture examples of each were used, these being named below, (see Chapter 7).

Fig. 6.6: Combined Network of Support and Motion



The stereotypes are:-

i. **CARRY**

The carried object inherits the support and effort of the carrier. The carrier motion can be any of the other kinds.

Picture examples:- People in train and Pole carried by man.

The CARRY examples chosen above represent CARRY-IN and CARRY-HELD type motions. A CARRY PART-OF might be the hair of a girl moving as she is walking along the road.

ii. **STAND**

There is no action and so no effort is present. Support is supplied by the ground or a substitute. Examples:- A television set standing in a room, lamppost. (This case was not tested).

iii. **WALK**

The ground or a substitute is the support while the effort comes from the object itself. This object can be animate or inanimate in nature. This is a controlled motion which means the effort is maintained and can be changed throughout the motion. Therefore the course of action is not inevitable and can be controlled.

Picture examples:- Animate - Bull and Man.
Inanimate - Car and Lorry.

iv. **PUSH**

The ground or a substitute, is the support while the effort is external to the object but applied constantly throughout the duration of the motion. Push or pull actions are both included, as the model does not distinguish between whether the source of effort is in front or behind the moving object. This is another example of a controlled motion.

Picture examples:- Haycart and Pram.

v. **ROLL**

The ground or its substitute provides the support while the effort is applied externally to the object and does not come from itself. The difference between a ROLL and a PUSH motion is that the source of effort is applied only at the start of the motion and not throughout its duration.

Picture examples:- Bowl and Hoop.

vi. **FLY**

The action takes place in the AIR and the source of effort is internal to the object which can be animate or inanimate in nature. The effort is continuous and provides a controlled motion.

Picture examples:- Animate - Bird and Bee.
Inanimate - Aeroplane and Helicopter.

vii. **JUMP**

This action takes place in the AIR but the source of effort is internal to the moving object itself and takes place only when the motion begins.
Picture examples:- Girl and Horse.

viii. THROW

This action takes place in the AIR and the object stays up for a period and then falls to the ground. The source of effort is external to the object and is only applied at the beginning of the action.

Picture examples:- Ball and Football.

ix. FALL

No effort needed caused by lack of SUPPORT.

Picture examples:- Man from broken drainpipe and Bomb from aeroplane.

x. FLOAT

The air forms the support of these light objects and is also its source of EFFORT i.e. the wind makes these objects move.

Picture examples:- Balloon and Clouds.

The ground is regarded by the model as fixed and immovable. There is no possible cause for it to move. (Exceptional circumstances such as earthquakes lie outside the system). If anything else is fixed to the ground e.g. a house or a lamppost, then this object too will lack the possibility of motion.

Things which do or can move are distinguished as objects. The model proposes that pieces of a scene are recognised as one object when all the parts of that same object move together. The individual pieces of an object are attached to each other, or the object is held by another object The conditions for a single object at rest are defined as follows:

a. Lacks being fixed so could move.

b. Requires some sort of support (without support, it falls).

There are however objects which lack being fixed, are not visibly supported by another object, yet are not falling e.g. a bird or an aeroplane. These objects must therefore have the special property of being able to hold themselves up - this being achieved through EFFORT.

There is a part of the network which establishes whether a thing under scrutiny belongs with or goes with other objects. When objects move together it is reasonable to expect to find them as part of/fixed, to/carried, by/resting, on/other things. This part of the network defines two further cases of movement by distinguishing the two possibilities:-

1. The object is fixed to the carrier,when support and motion are integrated.

2. The object rests on or in the carrier, when support and motion are differentiated.

In other words some CARRIED objects move as part of the carrier (e.g. the arms go with the body) whereas other carried objects only rest on the carrier (e.g. the saddle of a horse.) This category raises some interesting questions about the recognition of objects since the model assumes that all the pieces of an object must move together for it to be considered as one object.

This introduces a further link between motion and support, in that parts can be supported by wholes, these being important features which need to be considered in the genesis of the notion of the object itself and in the elucidation of the role of action in the development of this concept.

The model emphasises the fact that the course of certain movements can be changed or controlled during their duration. The effort to move the object is produced constantly throughout the motion such as in WALK and allows the path or speed of the motion to be changed. This is in contrast to a ROLL type motion where the effort is only present at the start and a rolling object's path is determined by its source of effort. This distinction is found in figure 6.4 for the motions of WALK, FLY and PUSH. This distinction is later referred to as a CONTROL/TIME difference (see 7.2.5).

This version makes a distinction between motion produced by **own effort** from that of the effort of an external **agent**. However if one examines the stereotypical case of WALK, which uses own effort, in reality this paradigm includes both animate and inanimate examples such as people and cars. Whether this version of the model should have catered for this finer distinction is a question which can only be answered by subjecting the model to test.

6.3 CONCLUSION

The previous informal model suggested that movement is conceptualised as taking place either on the ground or in the air. The formalized version makes this distinction even clearer by making explicit the differences between movements on the ground and in the air. It is because this later model differentiates basic motions with respect to a number of features that one testable aspect of the model is the degree of difference between motions. Another is the extent to which people agree that examples placed in the same category by the model are indeed similar.

This formalised model with clearly defined stereotypical motions, not only allows different sorts of questions to be asked about commonsense causes of motion but also suggests a methodology which could be used to probe this understanding. The questions this model raises includes:

1. Do people actually group motions as the model predicts and is this a natural way to explain motion?

2. Do people rate the differences between stereotypical motions as similar to those predicted by the theoretical model?

3. If the ideas about the causality of movement and the nature of objects which are the basis of this model are formed in early childhood, will primary school children recognise the differences between motions as predicted by the model?

4. What sort of methodology could be employed to answer the above questions?

Given the stereotypes,with examples of each, a matching task suggests itself as a possible methodology where subjects, over a wide age range, could be asked to compare pictures of representative examples from the nine stereotypical motions (STAND, a non-motion, would be omitted) and to rate the difference between these motions. Their responses could be compared directly with the theoretical predictions and so provide a test of the model. A fuller discussion of why a task of this nature was developed for the main study is given in section 7.1.2.

If this type of methodology is considered as a possible means of testing the model then the first three general questions raised above can be more sharply defined:-

1. Do people recognise the differences between stereotypical motions in the way proposed by the model?

2. Does this occur over a wide age range?

3. If there are differences between the model's predictions are the differences systematic with the age groups tested?

4. Are there any pieces of the model still missing?

5. Do children differentiate between animate and inanimate motion more strongly than suggested by the model?

6. Can the role of CARRY be investigated in more detail to see if an object is recognised as one object if all its pieces move together?

These issues provided important considerations in the design and choice of the instrument for the main study, which is discussed in the next chapter.

7. DESIGN OF THE MATCHING TASKS AND THEIR ADMINISTRATION

The purpose of this chapter is to describe the methodology used in the main study. The first section **How can the model be tested?** discusses different methods of testing tacit knowledge. The second, **Design of the Matching Tasks,** discusses the design and construction of the final questionnaires. The third section **Description of the three separate Matching Tasks** specifies the contents of each test. The fourth, **Sample,** describes the different groups of students involved and discusses the sampling process. The final section, **Administration,** describes the timing and the manner in which each matching task was given.

7.1 HOW CAN THE MODEL OF COMMONSENSE IDEAS ABOUT MOTION BE TESTED?

7.1.1 Introduction

The model of commonsense ideas about motion aims to explain or give a reasonable account of what most people think about movement. It provides a number of testable hypotheses about tacit conceptions of motion, in particular by specifying a number of stereotypical motions (figure 6.4). More importantly, the model defines the differences between these motions.

7.1.2 What would be an appropriate task to test the model?

Possible methods of testing a theoretical account of tacit knowledge fall into three major categories. These can be differentiated by the responses they ask subjects to make when explaining motion:-

1. Do people **produce** the same terms as the theoretical account?

2. Do people **agree with** the account given by the model?

3. Do people make **judgements** in accordance with the model's predictions?

The techniques which match the above classification are -

1. Interviews - using explanations as a source of data.

2. a. Repertory Grid Technique - using given constructs as a source of data.

   b. Making use of a number of explanations of motion based on the theoretical account and asking pupils if they agree with these explanations. (A computer model could be used in this way).

3. A paper and pencil task could be designed to test the model's predictions about similarity or difference between different motions. The subjects could be asked to compare pairs of motion, presented as pictures, and to say how different they thought they were by selecting from a choice of predetermined responses.

The appropriateness of each technique for use in the main study is discussed below.

1. Interviews

An interview methodology produces a number of children's explanations about motion. These explanations need to be compared with the theoretical account and the researcher has to judge whether the children's specific disclosures about motion can be interpreted in terms of the model. This is not so straight forward as first appears because the children could be using the terms of the model such as EFFORT and SUPPORT but not using them in a way predicted by the model. This means that they are using the terms just as ordinary words and not the strict sense defined by the theoretical account. For example EFFORT described by the model as the "go of things" and can be used to account for any type of force which makes things move. Children might only use the term EFFORT to talk about animate forces yet recognise that some sort of "EFFORT" is needed for any type of motion to take place. On the other hand the children may never use any of the terms or nomenclature of the model, throughout the course of the interview, but they may nonetheless explain motion in a manner which is consistent with the model. In either case it must be recognised that there is a long chain of inference between the subjects' explanation and the categorisation of the data for analysis. A way to overcome this particular problem would be to "put the model to the children" first and then note their response. However, there is the difficulty with this latter technique of the researcher suggesting the model to the children. It would then be difficult to determine whether the spontaneous responses of the subjects had really been captured.

The interview technique provides a good first test of the model (see Chapter 5.2) in that it provides an appropriate vechicle for exploring children's ideas. However, there are too many obvious objections for it to be used for a test of a well specified model, nor can it be used for interviewing large numbers of subjects across a wide age range.

2a. Repertory grids

The three ways in which knowledge can be elicited with this method have been previously discussed in section 5.3.2. Giving both constructs and elements to the subjects is the only technique that would serve in this instance and its use has three obvious objections:-

i. The subjects are being taught the model.

ii. It would be a too time consuming methodology with which to test a large number of subjects and

iii. The problem of interpretation of data persists.

2b. A computer model of the theory has been written in Prolog which produces explanations of motion. It would be a challenging but nonetheless time consuming exercise to develop an interview with this type of model to see whether subjects agree with the types of accounts of motion that the computer produces. Again the problems of interpretation and suggestion still remain with this technique.

3. Questionnaire

A paper and pencil matching task is certainly one of the most attractive choices to test the theoretical model. Such a matching task would ask subjects to **judge** the similarity of different motions as proposed by the model. Their responses could also be checked against the theoretical predictions in a quantitative way. The technique would be simple to administer to a large sample size and age range. This method, with its large number of comparisons has the advantage of making it difficult for the subject to consistently try to "guess what is wanted". This technique overcomes many of the problems associated with the other methodologies such as inference and suggestion and provides a good test of whether people do actually group motions as the model predicts. It would also be possible to ascertain then whether the model actually represents a natural explanation of motion. However, there is a disadvantage with this tool in that it does not collect any evidence regarding the subjects' reasons for choices.

7.1.3 A synopsis of reasons for choosing a Picture Paper and Pencil Task

The main practical reasons for conducting a survey with a questionnaire:-

a. More subjects could be tested within the time available, which allows for the possibility of testing over a wide age range.

b. The data would not be purely qualitative in nature, but will allow quantitative analysis.

c. Pictures could be used to represent the motions, one of several preferences being ticked to indicate similarity of the causes of motions. This technique would impose less verbal demands upon the subjects and could more easily be used by younger pupils, i.e. those of primary school age.

d. This design would allow identical tests to be given to a wide age range of pupils i.e. 7 - 16 year olds, ensuring that the results from several age groups could readily be compared with one another.

e. The interpretation of the question is left to the individual. Thus the model, apart from selecting the cases presented,is in no sense revealed to the subject.

7.2 DESIGN OF THE MATCHING TASKS

7.2.1 Introduction

Three separate matching tasks were devised to test the model The main task, Matching Task 1 was the main one and was specifically designed to test systematically every possible comparison between the nine stereotypical motions. The condition known as STAND which described objects at rest was omitted from the tests. There was no space in the main task to test more fully the role of ANIMACY and the status of CARRY and so two subsidiary tasks were devised to test these other factors. Although three separate tasks were used they were designed in a similar fashion. These general aspects are described below while the individual differences between questionnaires are discussed later.

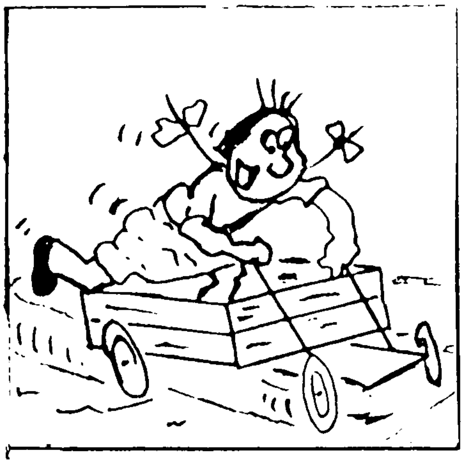
7.2.2 General description of the Matching Tasks

All three Matching Tasks consisted of an A5 landscape booklet with the instructions on the front cover and all bore the title "REASONS WHY THINGS MOVE". Each consecutive page contained pictures of two different motions which needed to be compared. Underneath the pair of pictures was the response box to be completed by the subject, who had to indicate whether the reasons why the two things move were very alike, a bit alike, a bit different or very different, by ticking the appropriate place. An example page is shown in Figure 7.1 below. This format was chosen since during trials it was found that the subjects preferred to indicate their choice of comparison per pair of motions on the same page, where the pictures were drawn and not on a separate answer sheet. They felt they could too easily lose their place in a test which was fifty questions long.

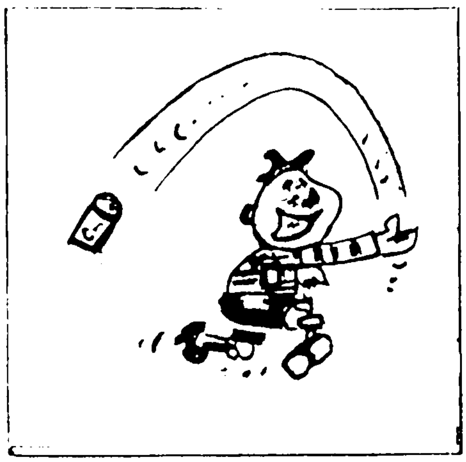
Figure 7.1: Sample page from Matching Task Booklet

1. Reasons for things moving

The go-cart moves



The tin can moves



The reasons why the two things move are

- ☐ very alike
- ☐ a bit alike
- ☐ a bit different
- ☐ very different

The second page, which contained the first pair of comparisons, was the same for each task. It contained a training example of pictures; which was not part of the actual test but was inserted as an example which could be done with the teacher's help, to make clear the nature of the task.

The two different pictorial examples of each motion were used alternately throughout each task. The pairs of comparisons after being systematically selected were then placed in a random order for the final construction of the booklet. This ordering is documented in appendix V for each task.

7.2.3 Pictures to represent the nine stereotypical motions

It was decided to include some replication, by using two examples of each stereotypical motion. A set of general criteria were needed to make the final selections and to decide upon the presentation of each diagram in the booklet. These were as follows:-

1. Each picture needed to be a clear case of one stereotypical motion.

2. The source of EFFORT needed to be easily recognised.

3. The source of SUPPORT should be clearly drawn and the state of the ground should be apparent, these being important features of the theoretical description.

4. The background features which set the scene of the action must be minimal but clear.

5. A label would be needed upon which to focus the action.

6. The pictures should describe reasonable everyday motions.

7.2.4 Selection of activities to be represented diagrammatically for each stereotypical motion

Table 7.1: Pictorial examples chosen to represent the stereotypical motions in Matching Task 1

STEREOTYPICAL MOTION		EXAMPLES CHOSEN TO REPRESENT MOTION
CARRY		People in train and Pole carried by man
WALK -	animate	Bull and man
	inanimate	Car and Lorry
PUSH		Haycart and Pram
ROLL		Bowl and Hoop
FLY -	animate	Bird and Bee
	inanimate	Aeroplane and Helicopter
JUMP		Girl and Horse
THROW		Ball and Football
FALL		Man from broken drainpipe and Bomb from aeroplane
FLOAT		Balloon and Clouds

The CARRY examples chosen above are different from each other which is not the case with the representive examples of the other eight stereotypical motions. This is because CARRY is a more complex motion and objects can be carried IN or HELD-BY the or form PART OF the carrier (see figure 6.4). The CARRY-IN/HELD examples proved to represent more realistic motions which would be easier to test in the main task and since CARRY is a more complex motion than the other eight it deserves special investigation in a separate task where its different facets can be examined in more detail (see 7.3.6). The example of passengers in a train is chosen to represent a CARRY-IN motion while a man holding a pole provides an example of a CARRY-HELD motion. The details of a separate Matching Task for CARRY are described later in Section 7.3.6.

7.2.5 Predicting differences between the stereotypical motions

In order to assess the differences between each of the stereotypical motions a simpler description based on the network and using its primitives of **support, effort** and **control/ time** was used as is shown in Table 7.2 below. (Later, more elaborate schemes were used).

Table 7.2: Differences of support, effort and control used to differentiate the classes of motion

CLASS OF MOTION	SUPPORT	EFFORT	CONTROL/TIME
FLY	Itself - effort	Other	+
FALL	None	None	-
FLOAT	By air	None	-
THROW	None (motion)	Other	-
WALK	Ground	Own	+
JUMP	None (motion)	Own	-
ROLL	Ground	Other	-
PUSH	Ground	Other	+
CARRY	Support other	Other	-

The differences between the nine classes of motion can now be numerically scored from the above table. This is illustrated by the examples of Throw and Fly. The support is different in each, since a flying object supports itself by effort while a thrown object has no support. There are also differences in effort. The flying object supplies its own effort while the thrown object has no effort of its own it is only provided by an external source of effort. Control is also dissimilar. Flying objects have their effort in the present and are controlled while thrown objects do not control their own motion. This leads to three differences between the two stereotypical motions. Each class of motion was compared with each other in this way and the differences were translated into a numerical score as shown below.

1 = no difference 3 = 2 differences

2 = 1 difference 4 = 3 differences

(It would have been better to score these 0, 1, 2, 3: the above system was used because my spread sheet would not count numbers of zeros).

The theoretical predictions between the classes of motion were constructed in this way and are summarised in table 7.3 below.

Table 7.3: Differences between classes of motion depicted by numerical score

	FLY	FALL	FLOAT	THROW	WALK	JUMP	ROLL	PUSH	CARRY
FLY	1	4	4	4	2	3	4	3	4
FALL		1	2	4	4	3	3	4	4
FLOAT			1	3	4	3	3	4	4
THROW				1	4	2	2	3	3
WALK					1	3	3	2	3
JUMP						1	3	4	3
ROLL							1	2	3
PUSH								1	3
CARRY									1

The basic distinguishing concepts which were used in the network to differentiate motion were those of SUPPORT, EFFORT and CONTROL and these were given equal weightings when constructing the theoretical scores. This was the first attempt at translating the differences between motion as described by the network into a numerical score and there was no reason not to assign equal values to the primitives. At this stage an animacy factor was omitted until the position was further clarified with Matching Task 2.

One of the weaknesses of the model is that it does not mention the relative importance of the primitives used to describe motion. This thesis attempts to investigate what this might be and whether any more descriptions are necessary if motions are to be grouped in a commonsense way. However, if the theory survives under these conditions then it would be a good first test and would support a view that it is not totally wrong!

7.3 DESCRIPTION OF THE THREE SEPARATE MATCHING TASKS

7.3.1 Matching Task 1

The main task consisted of 1 training example and 49 comparison pairs of pictures for examination and included three types of comparisons.

These were:-

i. Comparisons of different members of the same class of motion.

ii. Comparison of the nine different classes of motion with each other.

iii. Comparison of animate and inanimate members of the classes of motion of WALK and FLY only.

The latter comparison was included because the pilot study and repertory grid work had suggested that pupils would attribute difference based on animacy. This was therefore a first attempt to investigate the above phenomenon, which would be given further and fuller analysis in Matching Task 2.

The children were asked to rate the differences between the motion on a four point scale. This scale was used for all the Matching Tasks. Pairs of comparisons, using the two replications of each motion alternately, were systematically selected, and then re-arranged in random order.

7.3.2 Description of Matching Task 2 (Animacy Test)

A separate task was designed to test the notion of animacy. It made three animacy comparisons for each of the nine stereotypical motions. These included:-

Inanimate motion with inanimate motion.

Animate motion with animate motion.

Inanimate motion with animate motion.

These three different comparisons were tested for each stereotypical motion which made a total of 27 comparisons. (See Appendix V for order of examples in booklet).

7.3.3 Description of Matching Task 3 (Test of role of CARRY)

Matching Task three was developed to investigate more fully the role of CARRY in the commonsense model of motion. This task was designed to make comparisons between carry motions and their corresponding stereotypical motion to test whether the motion of the carried object is seen to move in the same way as the carrier of the same object. It was also intended to see if the comparison of different carry pairs would be seen similarily to the comparison of the corresponding stereotypical pairs e.g. would CARRY FALL and CARRY FLOAT be seen to be similar to FALL and FLOAT?

The sets of comparisons were constructed in the following way.

In the notation below X denotes one type of sterotypical motion while Y represents a different stereotypical motion.

i. **Comparison of CARRY-IN identities**

a. CARRY X   CARRY X

Two different pictures of an identical CARRY motion were compared to each other.
E.g. CARRY FLY with CARRY FLY

b. CARRY X   CARRY Y

Two different CARRY motions were compared.
E.g. CARRY FLY with CARRY FLOAT

ii. **Comparison of CARRY-IN identities with equivalent and different stereotypical motions**

a. CARRY X - X

A CARRY-IN motion was compared with its equivalent
single stereotypical motion.
E.g. CARRY FLY and FLY

b. CARRY X - Y

A CARRY-IN motion was compared with a different single stereotypical motion.
E.g. CARRY FLY and FLOAT

iii. Comparison of CARRY-IN and CARRY-HELD motions

A CARRY-IN motion was compared with its identical CARRY-HOLD motion. E.g. CARRY-IN FLY and CARRY-HELD FLY.

The carry task tested only the following five motions, FLOAT, FLY, WALK, PUSH and FALL. This test did not include ROLL, JUMP and THROW motions. The reasons for this decision were as follows. It was difficult to find realistic examples of ROLL, JUMP, THROW. Objects rolled or thrown rarely carry anything in reality. It was perhaps unfortunate not to have tested all aspects of the model in this case - but at least some comparisons were possible. Possibly a simple matching task is not the way to compare compound motions, because of the difficulty of knowing what to attend to. This difficulty was compounded when CARRY-PART OF comparisons were thought about for inclusion in this task. What features of the object should the subjects focus on when a CARRY PART-OF comparison was needed? For example with a JUMP should it be the mane of a horse. Could the fingers of a person participating in a WALK type motion count? The real difficulty here is that if the part of the object does not move independently then it cannot be attended to as an object and if it does move more independently then you cannot draw the subjects attention to it. In the end CARRY-PART OF comparisons were omitted from the investigation. This difficulty highlights the problem of trying to investigate CARRY in the same format as the other tasks. In fact with this design **two** comparisons need to be made between the pairs of given examples: those of the carrier and the carried.

CARRIED objects can be carried IN or HELD-by the carrier. It was too difficult to systematically vary all the CARRY IN and the CARRY-HELD comparisons, since the recursive nature of CARRY escalates the number of examples to be compared which would produce too many items for the subjects to consider within a reasonable time span.

All these comparisons gave rise to a total number of 41 examples (in addition to the first training example) and these were then placed in a random order for the final version of the test booklet, as shown in Appendix V.

7.4 SAMPLE

7.4.1 Introduction

The research was designed to see whether the commonsense model provided a reasonable account of everyday thinking, and whether these commonsense ideas about dynamics persisted with age and physics teaching. Therefore for the main part of the study which would be examined with Matching Task 1 the population tested needed to include subjects covering a wide range age and physics background. This was done by selecting:-

a. The youngest possible primary children able to be tested with this methodology. The youngest were seven years old.

b. An older group of primary school children who would still not have any formal physics training. Ten year olds were chosen.

c. A group of secondary school children who had received some integrated science instruction: twelve years of age.

d. A group of secondary school pupils' who had selected to follow a physics course to 'O' level. These were fourteen years of age.

e. A group of sixth form students who had chosen to study different subjects, some of whom were following an 'A' level Physics course. All of these pupils' would have studied at least one science subject to 'O'/C.S.E. level but not necessarily physics.

7.4.2 Description of the sample used for Matching Task 1

Ten groups two each of (a) to (e) above were given Matching Task 1. They were taken from four different schools in Hertfordshire, chosen because the researcher had easy access to them and they had agreed to provide pupils for more than one test. Two Junior Mixed Infant

Schools (designated with letters A and B) and two all-ability secondary schools participated in the experiment (given letters C and D in the following tables).

Table 7.4: Table describing science curriculum followed by the four schools taking part in the research

SCHOOL	SCIENCE CURRICULUM
A	General science taught as part of whole curriculum
B	General science taught as part of whole curriculum
C	Integrated science taught for the first two years. Pupils took separate Physics, Chemistry and Biology classes in the third year and then choose at least one of these to study to 'O'/C.S.E. level.
D	Combined science taught for the first three years. Pupils then choose to follow individual science subjects or took a combined science exam course.

Table 7.5 summarises the main features of these groups.

Table 7.5: Table describing schools and pupils participating in Matching Task 1

Group	School	Age (years)	School Class	Current Science Teaching	No. of Boys	No. of Girls	Total No. of Students.
1	A	7	Infant	General	7	13	20
2	B	7	Infant	General			20
3	A	10	Junior	General	9	11	20
4	B	10	Junior	General	13	7	20
5	C	12	Second year Secondary.	Integrated Science	15	12	27
6	D	12	Second year Secondary.	Integrated Science	14	14	28
7	C	14	Fourth year Secondary.	Physics 'O' Level	9	20	29
8	D	14	Fourth year Secondary.	Physics 'O' Level	11	9	20
9	C	16	First year Sixth/ Secondary.	Mixed 'A' Levels	16	4	20
10	D	16	First year Sixth/ Secondary.	Mixed 'A' Levels	12	8	20

7.4.3 The sample used for Matching Task 2

Schools A and C were used for this test, only two age groups being tested. These were seven and 16 year olds, it having been decided to test the extreme ages. A smaller sample was used because if the animacy effect was as prevalent as suggested then it should be found both in the youngest and oldest pupils tested. These groups are not identical to groups one and nine used in Matching Task 1 above.

Table 7.6: Table summarising the main features of the groups used to test Matching Task 2

Group	School	Average Age (years)	School Level	Current Course	No. of Boys	No. of Girls	Total No.of Students
11	A	7	Infant	General	14	16	30
12	C	16	First year Sixth/ Secondary.	Mixed 'A' Levels	18	9	27

7.4.4 The sample used for Matching Task 3

Schools A and C were used for this test and three separate age groups tested, 7, 12 and 16 years of age. The seven and twelve year olds were not the same groups as tested previously. However the sixteen year olds were the same group as tested in Matching Task 2 i.e. group 12 was used twice.

The extreme ages were tested plus one group which fell in the middle. Three groups were chosen because it was thought that the seven year olds might produce different answers to the other groups because of their egocentricity.

Table 7.7: Table summarising the main features of the groups used to test Matching Task 3

Group	School	Average Age (years)	School Level	Current Course	No. of Boys	No. of Girls	Total of Students
13	A	7	Infant	General	12	18	30
14	C	12	Second year Secondary.	Integrated Science	13	17	30
12	C	16	First year Sixth Secondary	Mixed 'A' Levels	11	21	32

7.5 ADMINISTRATION OF TASKS

Each task consisted of a booklet with an identical general format and all the pupils completed them in the same way. However the administration of the tasks with infant and junior pupils was more structured. The instructions were read aloud to the pupils and they were asked to comment upon anything they did not understand. The first example was worked through together with the pupils and later the picture captions were read aloud to them as they completed each example to avoid any difficulties which some children had with their reading.

The secondary school pupils read the instructions themselves but were also asked to comment upon anything which they did not understand. The first example was worked through with them so they were clear about what to focus on during the questionnaire but they completed all the examples at their own pace as they had no difficulty reading the picture captions. The Tasks occupied between thirty and fifty minutes.

The survey was administered in three phases. The main study i.e. Matching Task 1 was administered in June 1987, Matching Task 2 in October 1987 and finally Matching Task 3 (the CARRY task) in November 1987.

8. ANALYSIS OF MAIN MATCHING TASK (TASK 1)

This chapter presents the analysis of Matching Task 1. It divides itself into seven sections, 8.1 **Introduction** describes the aims of the task. 8.2 **Methodology of Analysis** reviews the techniques used to assess how well the empirical data fitted the model's predictions for this and the subsequent other two tasks. 8.3 **Comparison of theoretical and empirical data**, reports the match between the model's predictions and the results from Matching Task 1. 8.4 **Discussion of scatterplots**, shows where the results from each age groups tested differ from the theoretical predictions. 8.5 **What is the consistency of response?**, summarises the similarity and variability of judgements found between the different ages. 8.6 **Possible causes of mismatch between empirical data and theoretical predictions**, identifies potential problematic pairs of comparisons and recalculates the correlations with those examples removed to see how these particular examples interfere with the model's predictions. 8.7 **Conclusion** summarises the main findings from this questionnaire.

8.1 INTRODUCTION

Matching Task 1 was designed to systematically test children's ideas about the differences between the nine stereotypical motions described by the model and to compare the children's responses with the predictions made by that theoretical model. Five different age groups were tested and so the results are presented for each of these separate ages (7, 10, 12, 14 and 16 years) together with a mean value for the whole sample.

8.2 METHODOLOGY OF ANALYSIS

The main aim of the analysis for Matching Task 1 (and the other two Matching Tasks described in Chapters 9 and 10) was to answer the following questions:-

i. How well does the empirical data fit the predicted values?

ii. What similarity is there between the responses of the different ages tested? and

iii. How much variation is there, at each age, in the judgements of similarity of pairs?

Although there is some variation within the individual chapters the main types of analysis used for each task, to answer the above questions, were similar:-

i. Rank correlations to judge the theoretical predictions against the empirical data.

ii. Wilcoxon signed ranks test of

a. The mean values - to judge similarity of responses between ages and

b. The standard deviation divided by the maximum standard deviation - to judge variability of responses.

The final conclusions which can be drawn from the results of all three Matching Tasks are discussed in Chapter 11.

This chapter also speculates about the distinctions the children are making which were not indicated by model, and could account for the observed differences between the theoretical predictions and the pupils actual replies.

In order to assess how well the empirical data fitted the predicted values it is important to see if the pupils put the pairs of motions into the same groups as suggested by the model. Since Spearman's rho is based upon ranks it has two special properties. It is less affected by outliers or extraordinary values than the ordinary correlation coefficient. The rank of the largest value depends only on the sample size and not on the magnitude of that value, so the value can be arbitarily large without altering rho.

Spearman's rho also remains the same even if x or y are transformed by a monotone function e.g. the ranks of log (theoretical value) will be the same as the ranks of "theoretical value". Values of rho can vary from -1 to 1. If value of rho is near 1 or -1 then the conclusion is not that there is a linear relationship between x and y but there is a **monotone** relationship between them. If rho is near zero then there is no evidence for a monotone relationship.

Rank correlations were preferred to Pearson correlation because the scale of the predictions is at best ordinal. In fact, the Pearson correlations never differed markedly from the rank correlations. Scatter plots showing empirical ratings versus theoretical prediction, together with their rank correlations, are given, for each age group.

The Wilcoxon signed ranks test were used to investigate:-

i. The similarity of judgement between the ages tested, and

ii. The variability of these judgements.

The standard deviation divided by the maximum standard deviation was used to assess the variability of judgements. The maximum possible standard deviation with mean m, on a scale 1 - 4 was calculated as follows:-

$$\text{maximum standard deviation} = \sqrt{(m-1)(4-m)}$$

The advantage of the Wilcoxon test over a t test for the purpose of this analysis is that it is not legitimate here to use an interval scale but the ordering of the scores is justifiable.

8.3 COMPARISON OF THEORETICAL AND EMPIRICAL DATA

Correlations were calculated both including and excluding the comparisons of members of the same sterotypical motion, i.e. the identities. This was done to gain some information about the role the identities play in the fit between theoretical and empirical data. It seems reasonable to suggest that children will recognise members of the same class of motion as more similar than pairs from different classes of motion and the predictions may fit better here even if the predictions between different classes of motion do not fit the theoretical predictions so well. Therefore the inclusion of identities will probably contribute a large part of any agreement between theoretical and empirical data. (See table 8.1 below.) Figures 8.1 and 8.2 below illustrate the shape of the two idealised scatterplots to be expected when:-

a. a correlation is found which is due only to the inclusion of identities and

b. a correlation is found which is not just due to the inclusion of identities.

Figure 8.1: Idealised Scatterplot of a correlation which is due only to the inclusion of identities

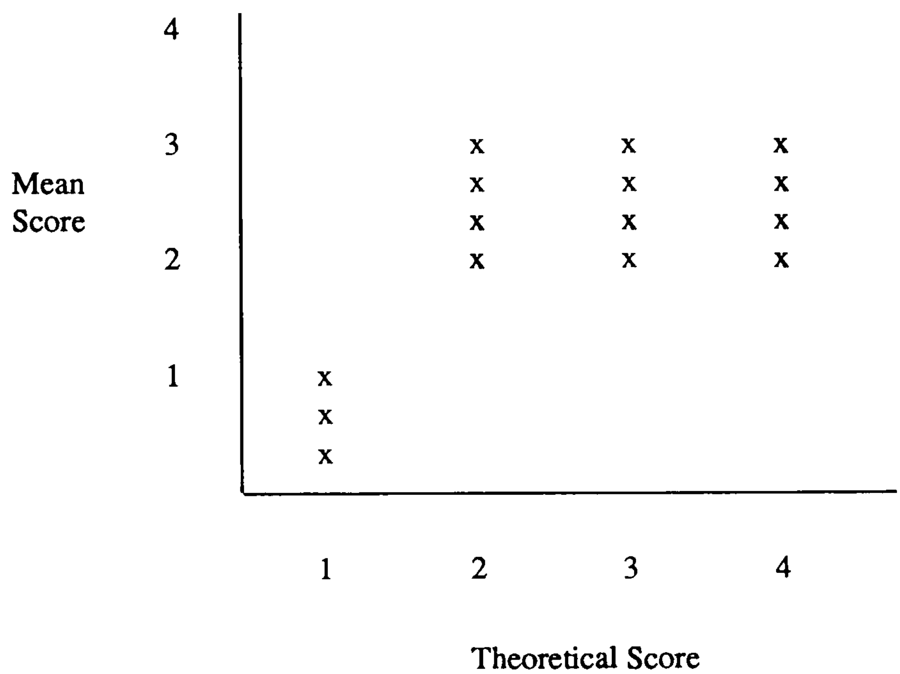


Figure 8.2: Idealised Scatterplot of a correlation which is not just due to the inclusion of identities

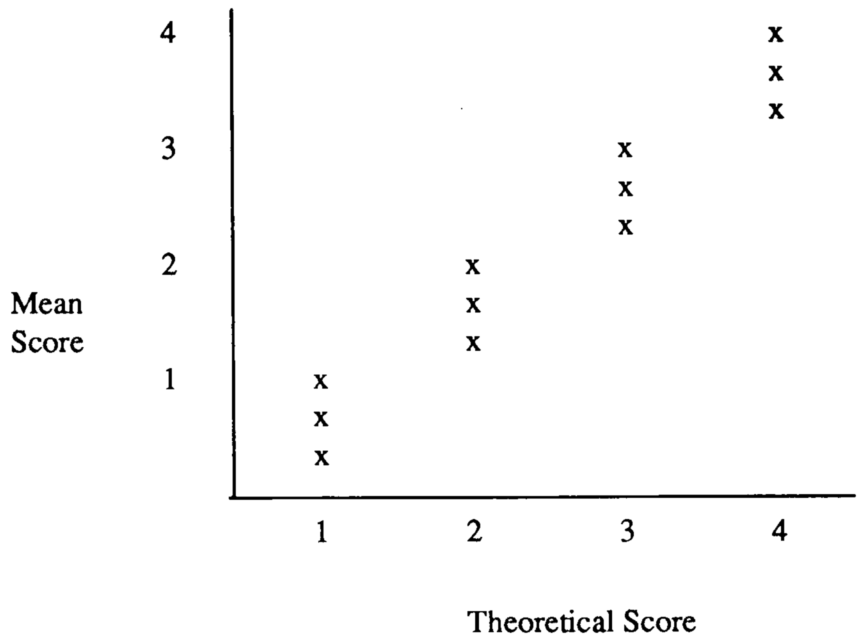


Table 8.1: Correlations with theoretical position; comparison of 'identities' have been included and excluded (n = 49)
(n = 36)

	Sevens Rank	Tens Rank	Twelves Rank	Fourteens Rank	Sixteens Rank	Mean Rank
With Identities	0.680	0.620	0.655	0.750	0.720	0.698
Without Identities	O.292	O.318	O.278	O.513	O.406	O.344

The correlations, including identities, are reasonably large (0.62 to 0.75), indicating a substantial agreement between the model's predictions and children's judgements. It appears that the correlations are rather higher for the two oldest groups (14 and 16), and rather lower for the younger children. Removing the identities reduces all the correlations, (0.28 - 0.51). The best match is for the fourteen year old group, and the worst for the twelve year olds. As above, correlations for the older children remain higher than those for the younger children. Appendix VI reports the children's actual responses to Matching Task 1. The theoretical predictions with which these actual results were compared are found in Chapter 7.

8.4 DISCUSSION OF SCATTERPLOTS

8.4.1 Introduction

Scatterplots of empirical versus theoretical values are discussed in relation to the correlations to identify the sources of the correlations. The scatterplots are given in figures 8.3 - 8.8 and include the identities.

The scatterplot produced by the mean scores of the total population is discussed first to look for a general pattern produced by the data as a whole. Specific problems are then illustrated with respect to all ages and then to particular age groups tested.

8.4.2 Scatterplot of the mean scores of the total population sampled

As expected from the correlations the scatterplot is generally fitted by a line of positive slope. The identities account for most of the positive correlation, because when they are removed, much less difference is seen between the separation of items within columns three and four.

It seems that children did regard as very similar motions predicted by the model to be 'identical'. However, the predictions of differences between non-identical sterotypes are much less good. One possible reason for this may be that the model does not take animacy into account - note that animate/inanimate comparisons identified on the plot, tend to occupy discrepant positions. Another noticable discrepancy is ROLL, THROW which are seen as more similar than predicted.

FIG. 8.3 SCATTERPLOT OF MEAN SCORE AGAINST THEORETICAL SCORE OF FIRST FORMALISED VERSION OF THE MODEL.

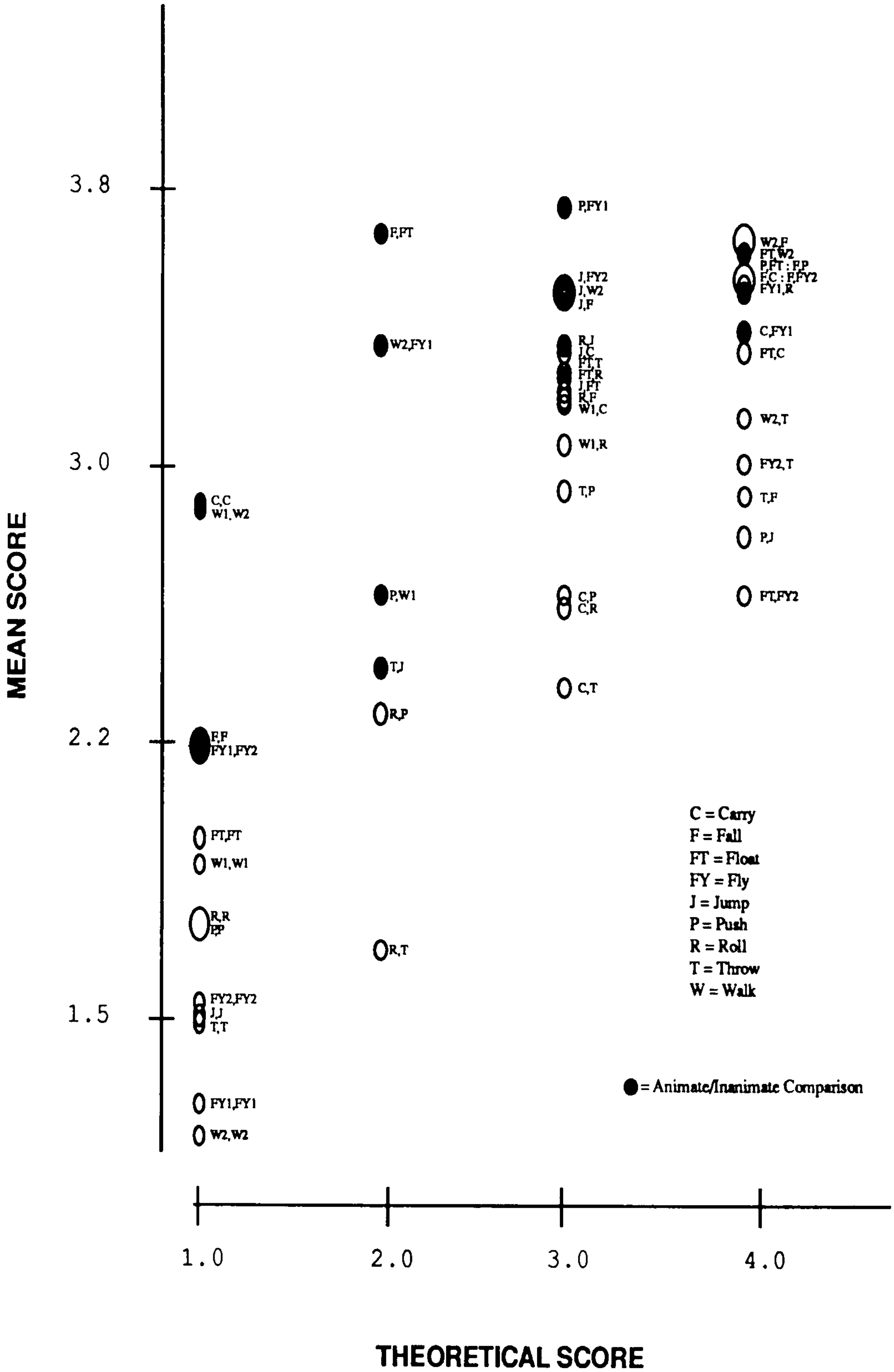


FIG.8.4 SCATTERPLOT OF SIXTEENS' MEAN SCORE AGAINST THEORETICAL SCORE OF FIRST FORMALISED VERSION OF THE MODEL.

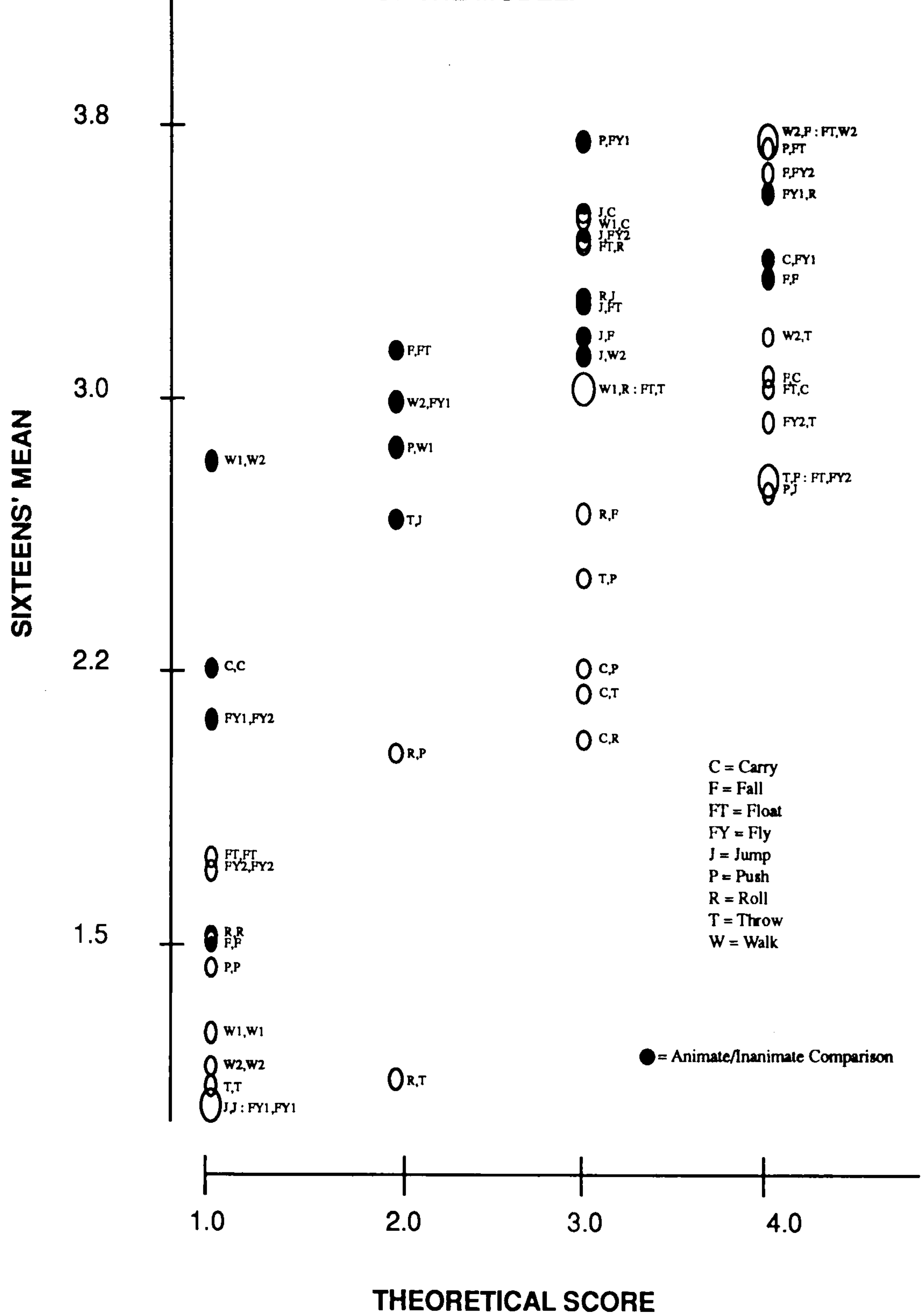


FIG.8.5 SCATTERPLOT OF FOURTEENS' MEAN SCORE AGAINST THEORETICAL SCORE OF FIRST FORMALISED VERSION OF THE MODEL.

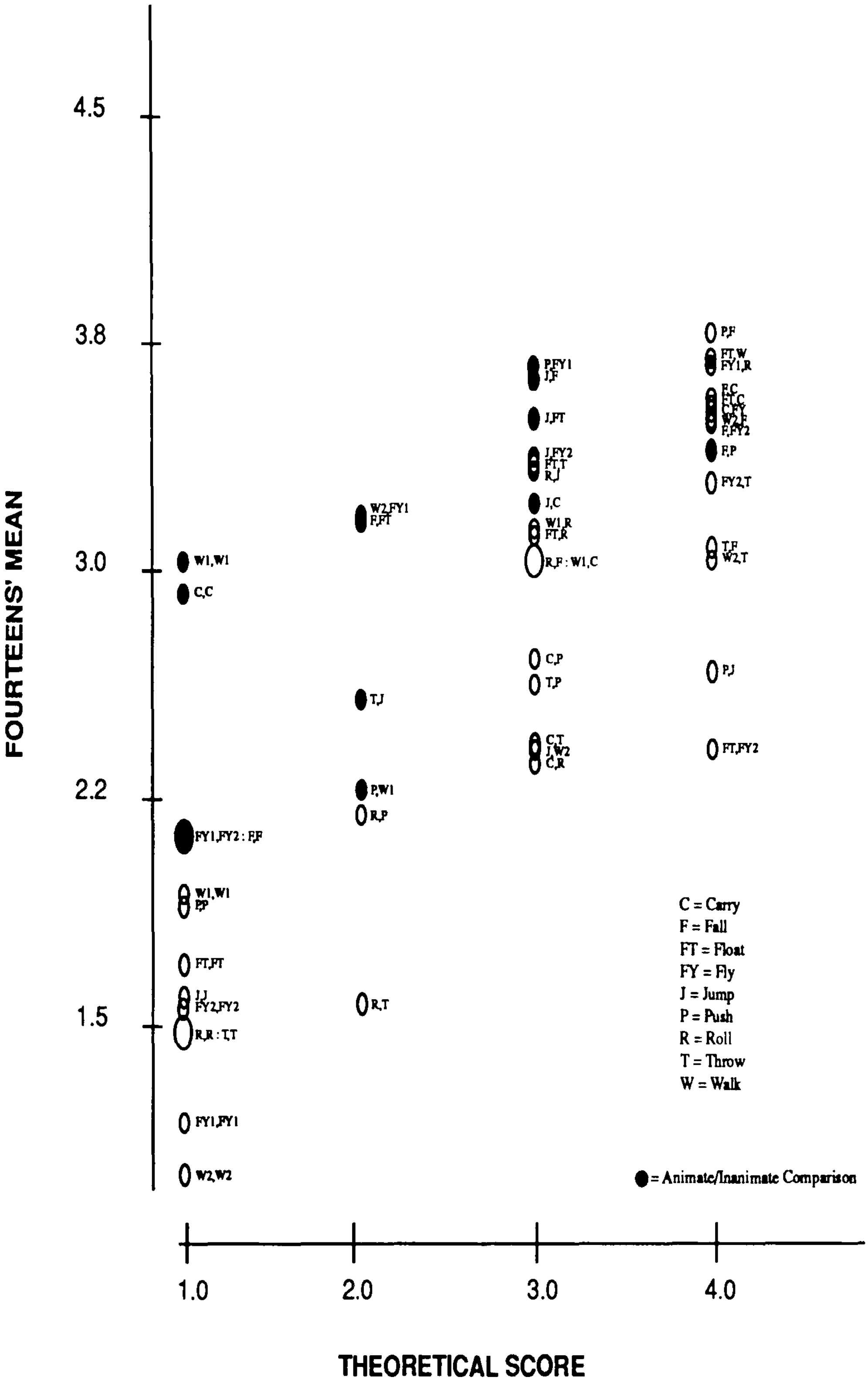


FIG.8.6 SCATTERPLOT OF TWELVES' MEAN SCORE AGAINST THEORETICAL SCORE OF FIRST FORMALISED VERSION OF THE MODEL.

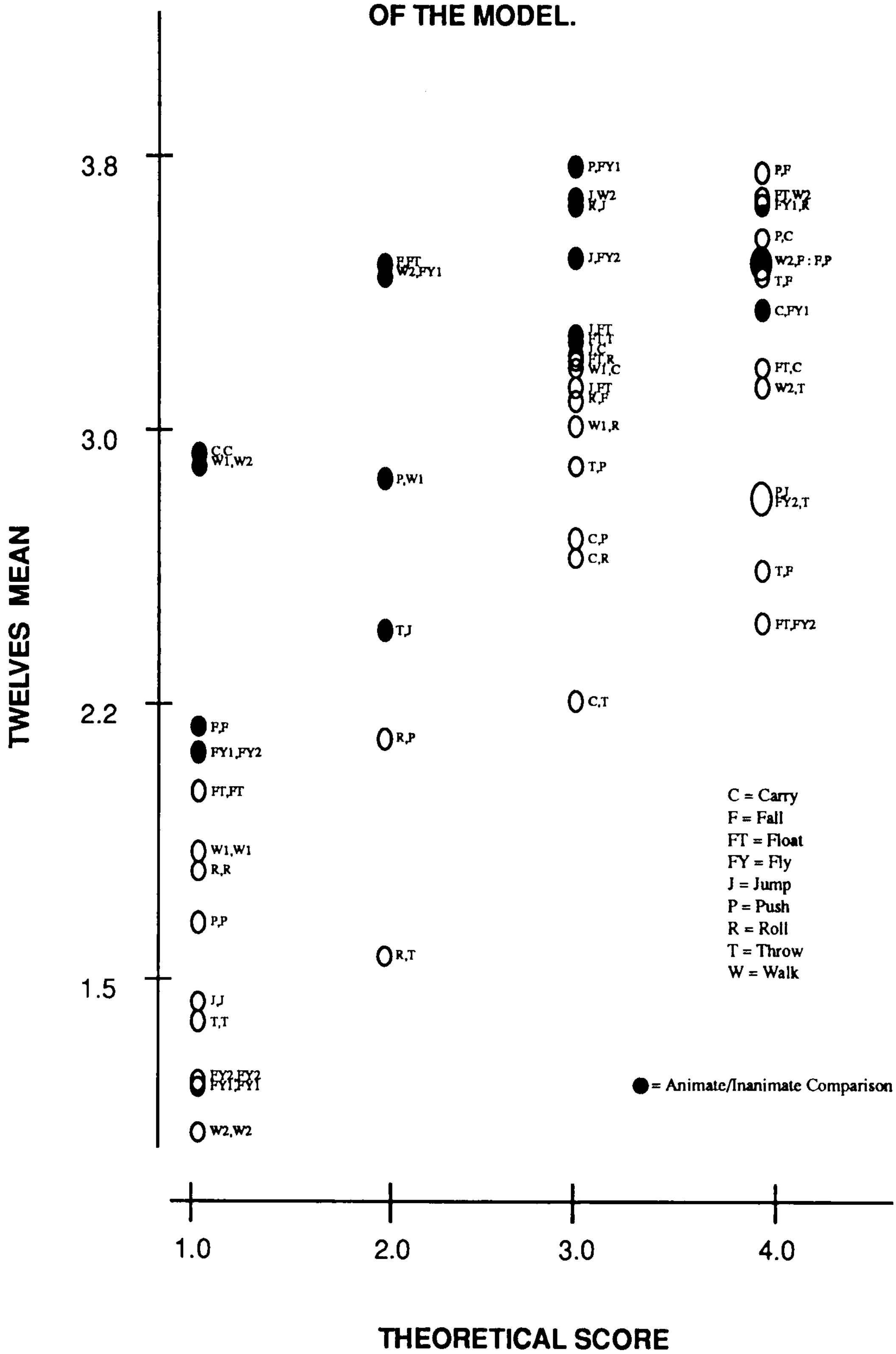


FIG. 8.7 SCATTERPLOT OF TENS' MEAN SCORE AGAINST THEORETOCAL SCORE OF FIRST FORMALISED VERSION OF THE MODEL.

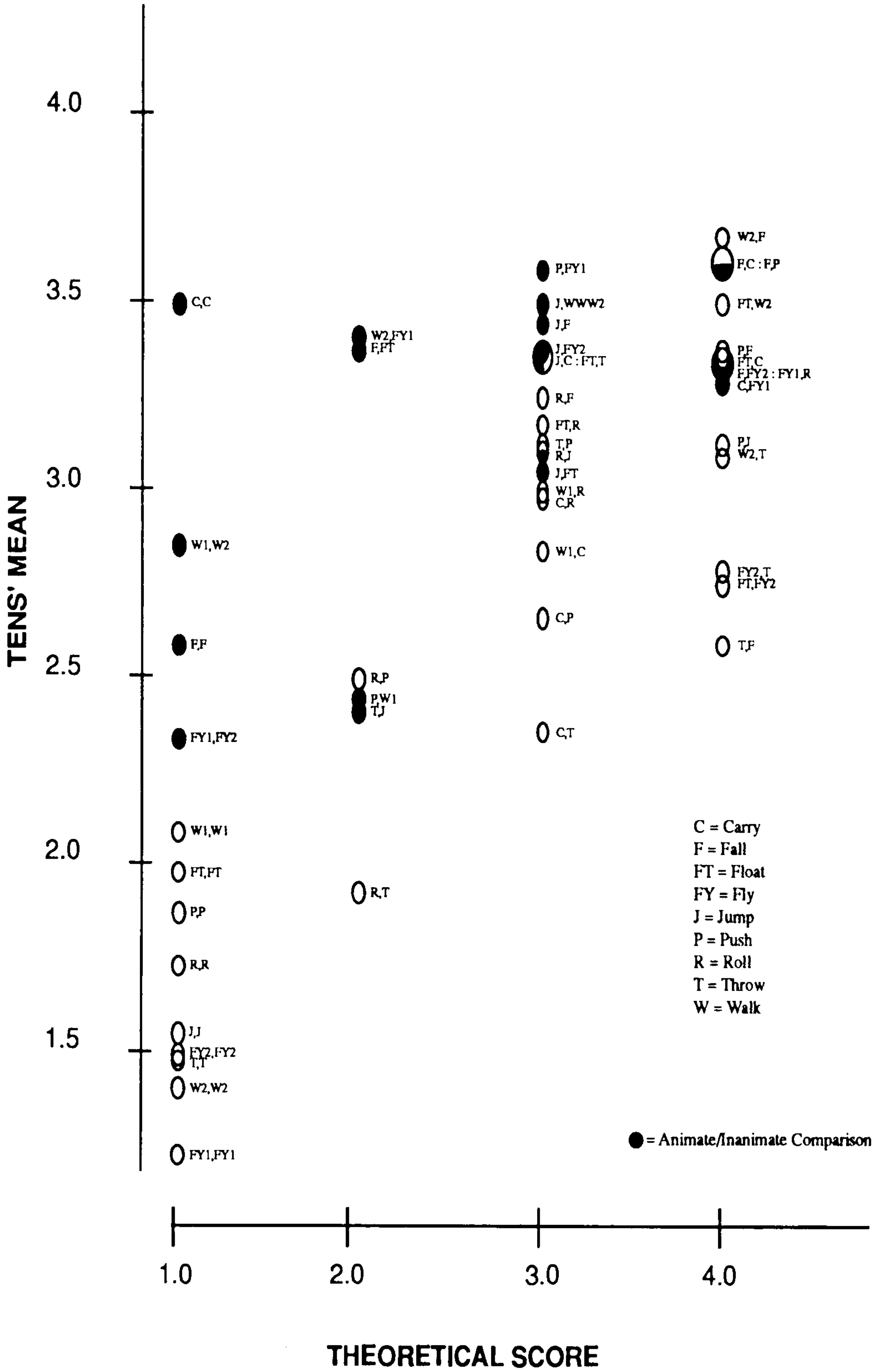
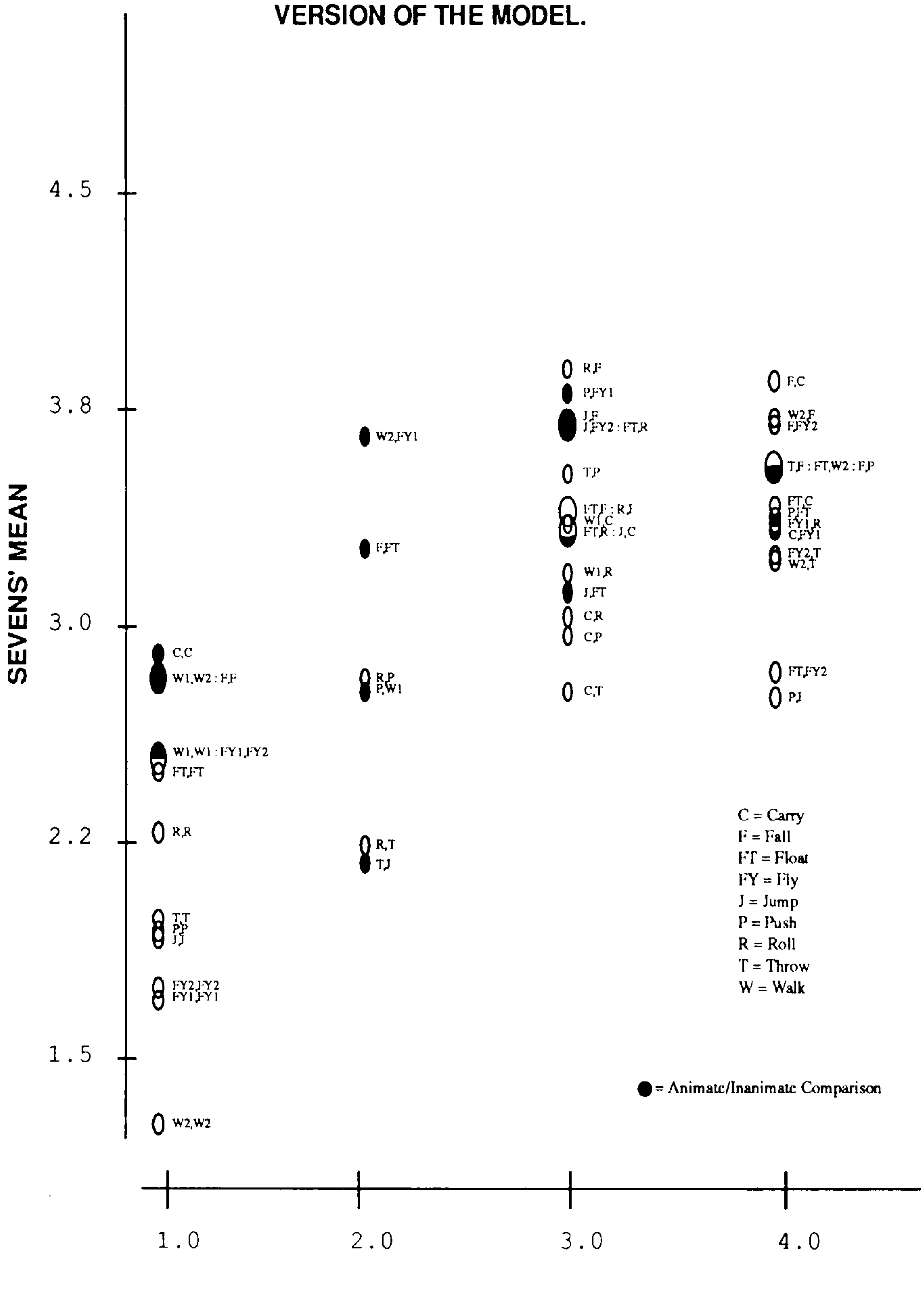


FIG. 8.8 SCATTERPLOT OF SEVENS' MEAN SCORE AGAINST THEORETICAL SCORE OF FIRST FORMALISED VERSION OF THE MODEL.



8.4.3 Problems found in the scatterplot of the mean scores of the total population sampled

The identities are not as closely grouped as might be expected. In fact their values range from 0.2 - 2.8. There are a number of factors which could explain these unpredicted differences:-

i. The role of animacy

The difference between animate/inanimate comparisons of WALK, WALK and FLY, FLY are greater than predicted by the model but these particular examples were introduced into Matching Task 1 because it was thought that animacy differences between moving objects would introduce another distinction between movements as yet not made explicit by the commonsense model.

ii. The selection of examples to represent CARRY

The CARRY difference is greater than the perceived difference between identities of the other sterotypical motions. This is not such a surprising result as at first appears since the examples chosen to represent CARRY in this task were CARRY-IN and difference in animacy and so of the identities these were in theory the most different. The model suggests that CARRY is a complex motion in the sense that a carried object inherits both the support and motion from the carrier and requires further clarification. The role of CARRY is tested more fully in Matching Task 3 and is reported later in chapter 10.

iii. Subjects discriminating between accidental and purposeful action

The FALL identity comparisons too do not match well with the theoretical predictions. The examples chosen to represent FALL; were a man falling from a broken drainpipe and a bomb dropping from an aeroplane. Some secondary school children suggested why these two examples should be viewed differently. They explained that a man does not normally intend to fall off a drainpipe and so his motion was considered to be accidental. On the other hand, a bomb is deliberately dropped from an aeroplane and so its motion is intentional.

Among the examples which were ranked with a theoretical difference of 2.0 (i.e. those which appear in column two of the scatterplot) the ROLL THROW comparison was seen as closer than its predicted value. In fact the children perceived less difference between the ROLL THROW comparison than the PUSH PUSH, FLOAT FLOAT and WALK WALK (animate) pairs of motions. This result could be explained by the design of the matching task itself. The questionnaire required the children to focus upon the reasons why two given objects move. It could be that with the ROLL and THROW comparisons the children focussed only on the source or origin of these motions, which both require an external source of motion. The pictures focus on the beginning of the motion and the thrown ball is seen only travelling in the upward direction. In each case the cause of ongoing motion is identical. Each ball is given a force from an external agent. This force or effort is used to propel the ball forward, whether it moves in the air or on the ground. The ball comes to rest when the force runs out in either medium and it could well be that differences in support are ignored by pupils for this example.

There are a number of comparisons, a PUSH JUMP, FLOAT FLY and three THROW pairs of motions, which were seen as closer than predicted by the model, while there are some JUMP and FLOAT comparisons where the differences were larger than predicted by the theoretical model. This result suggests that there could be problems with the theoretical differences predicted between JUMP, FLOAT and THROW motions or that the mismatch could be due to animacy differences. These suggestions are discussed more fully in section 8.6.

8.4.4 Problematic examples found in the responses made by the sixteen year olds

The sixteen year olds' pattern of response was similar to that of the mean scatterplot and fit the theoretical pattern better than the mean scores. The identities are more closely grouped together with the exception of the CARRY CARRY comparison, which stands apart from the others. The examples which were given a ranked theoretical difference of two again form a closely knit group with the one exception of the ROLL THROW comparison, which was seen as far more similar than expected. (Empirical value of 1.12).

The order of the examples which had ranked theoretical scores of 3 and 4 are similar to those found on the mean plot. There is a much bigger spread of examples for a ranked score of 3 while the pairs of motions with a ranked theroetical score of 4 are more closely grouped together.

8.4.5 Problematic examples found in the responses made by the fourteen year olds

The main difference between the fourteen year olds' data and the mean scatterplot is that for this age the subjects saw the WALK1, WALK2 comparison as more different than the CARRY, CARRY comparison. The examples with ranked theoretical score of 3 and 4 were more spread out than in the mean scatterplot, while the comparisons for a ranked theoretical score of 2 formed a more closely knit group.

8.4.6 Problematic examples found in the responses made by the twelve year olds

The scatterplot of the twelve year olds is very similar indeed to that of the graph produced by the mean values. The minor differences are seen in the examples with a ranked theoretical score of 2. Here the examples do not fall into three distinct regions. Only one group is identified and consists of the FALL, FLOAT and WALK2, FLY1 pairs of motions which were seen as more different than the others in this column. The other four examples with a ranked theoretical score of 2 are more spread out. The ROLL, THROW pair is seen as more similar than the ROLL, ROLL comparison. Among the examples with a ranked theoretical score of 4 the THROW, FALL pair is seen as less different than in the mean group and closer to the results obtained from the 10 year olds.

8.4.7 Problematic examples found in the responses make by the ten year olds

The ten year olds saw the CARRY CARRY comparison as more different than the other identities. In fact this value stood apart from others in this column. There is a larger spread of results in column 3 but a similar ordering of examples as shown in the general scatterplot. Among the examples with a ranked theoretical score of 4 there are three pairs which are seen as more similar than the others in this group. These are THROW FLOAT, FLOAT FLY2 and THROW FLY2 comparisons. It is only the ten year olds that saw the THROW FLOAT pair of comparisons as the least different in the theoretical range of 4.

8.4.8 Problematic examples found in the responses made by the seven year olds

The main differences between the seven year old responses are as follows:-

The CARRY CARRY and WALK WALK difference is greater than the perceived difference for the other identities.

The THROW JUMP difference is smaller than expected while the ROLL FALL difference is greater than the others which had a theoretical predicted difference of 3. For the comparisons which had a predicted difference of 4 the differences between FLOAT FLY2 and PUSH JUMP comparisons is smaller than expected.

8.4.9 Summary

Within the identities, the older children saw the inanimate/animate comparisons of WALK as more different than those of CARRY. The CARRY-IN/HELD distinction was recognised more clearly by the seven and ten year olds than by the sixteen year olds. Other CARRY comparions did not fit the theoretical predictions which suggests that the role of CARRY requires further clarification.

The ROLL THROW comparison was seen by all groups of children to be more similar than the model's prediction and this could well be the fault of the pictures chosen to represent these pairs of motions as described in section 8.4.3. The seven, ten and twelve year old pupils identified some of the FLOAT comparisons more differently than expected, which suggests that the theoretical role of FLOAT may not be quite correct or that the examples chosen to represent FLOAT may have caused unanticipated difficulties. Other differences were perceived by the children for some JUMP comparisons and this could be expressed by the pictures used to represent some of the JUMP motions (i.e. a horse jumping in the downward direction). These ideas are discussed in more detail in Chapter 11.

8.5 WHAT IS THE CONSISTENCY OF RESPONSE?

The model suggests that children form their ideas about the causes of motion very early in their development and so should be using these ideas to make sense of the world from an early age. Thus the prediction is that seven year olds should be using the same type of reasoning as the sixteen year olds. If the model's account of a common mental structure is correct then the children of all ages should respond to the questionnaire in a similar way.

In order to test this prediction children's judgements about pairs of comparisons were analysed in two separate ways, using the Wilcoxon signed ranks test.* This analysis allows the following two questions to be investigated.

1. Do children of different ages identify the pairs of motions similarly? and

2. Is the variability in responses similar for each group tested?

In order to answer the question whether children of two different ages put the comparisons in the same order, or not, each comparison given by children of different ages was compared by rank order. These results are shown in table 8.3. The T values for the 10/14 and 12/14 comparisons are within the 95% confidence limits, indicating there is not enough evidence to reject the hypothesis that any differences arose by chance. (For n = 49, 95% limits for T are 512 -713). For all the seven and sixteen year old comparisons plus the 10/12 comparison the value of T falls outside the 1% significance level, supporting the view that there are real differences between the groups in their judgements of examples.

* This test is here used to compare results from different age groups on the same pairs of motions.

Table 8.2: Wilcoxon Test to see if the different aged pupils compare the identical pairs similarly

T = T Values n = 49

	Sevens	Tens	Twelves	Fourteens
Tens	144*			
Twelves	199*	474*		
Fourteens	197*	574	579	
Sixteens	197*	353*	318*	323

* Values outside 95% confidence limits

The variability of judgements was analysed by dividing the standard deviation by the maximum value it could have for the observed mean. This value was ranked for each pair of comparisons by age as shown in table 8.5. The T values are high for seven/fourteen, seven/sixteen and fourteen/sixteen comparisons which indicated there is no real difference in variability between the ranks while the low values of T for the other comparisons support the view that there are real differences between the ranks.

Table 8.3: Wilcoxon Test to determine the differences in variability of responses by each age group

T = T Values n = 49

	Sevens	Tens	Twelves	Fourteens
Tens	238*			
Twelves	101*	370*		
Fourteens	543	203*	69*	
Sixteens	517	290*	153*	602

* Values outside 95% confidence limits

FIG. 8.9: MATCHING TASK 1. 7S' DATA.

Plot of mean versus sd./sd.max.

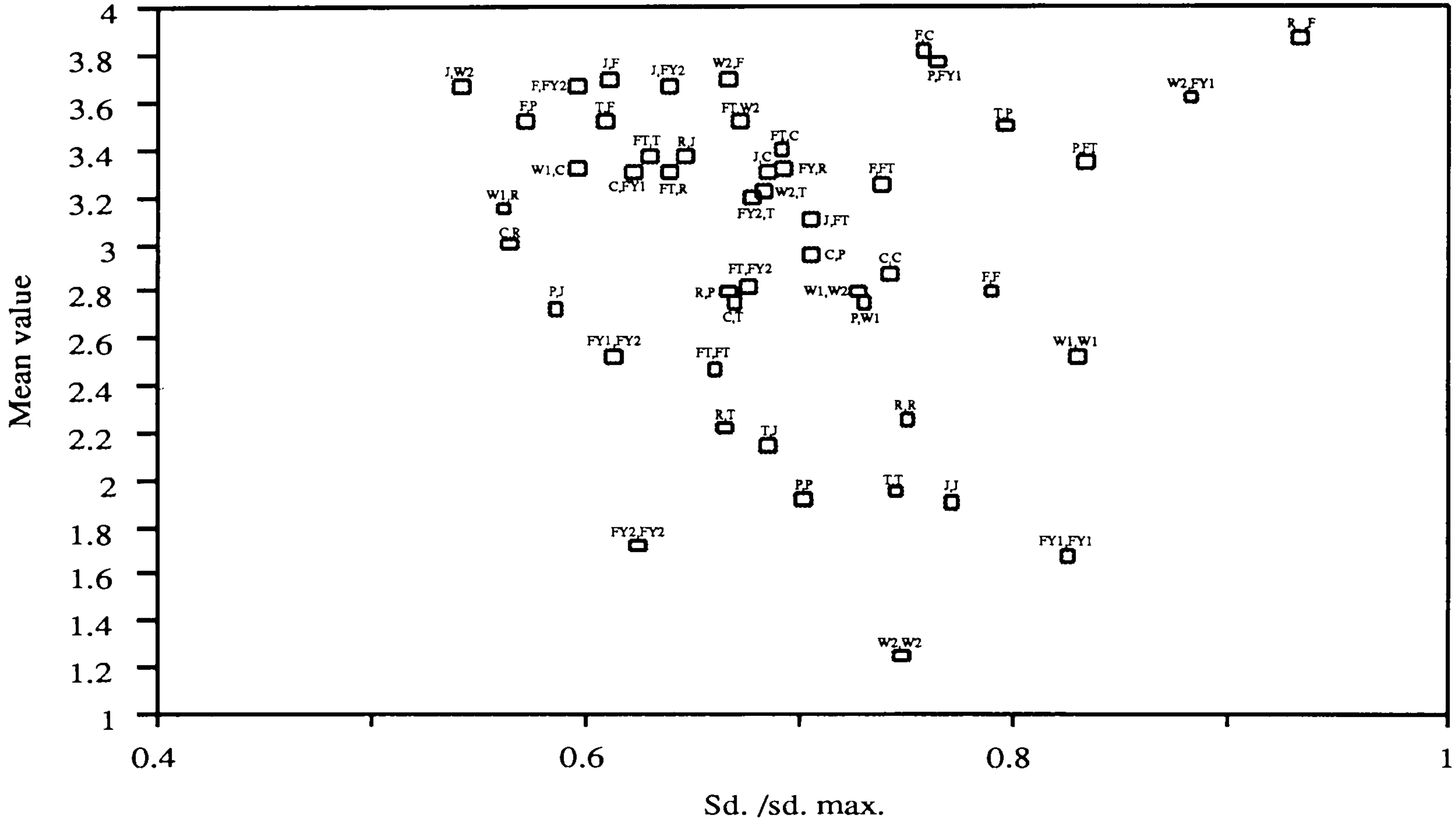


FIG. 8.10: MATCHING TASK 1. 10S' DATA.

Plot of mean versus sd./sd.max.

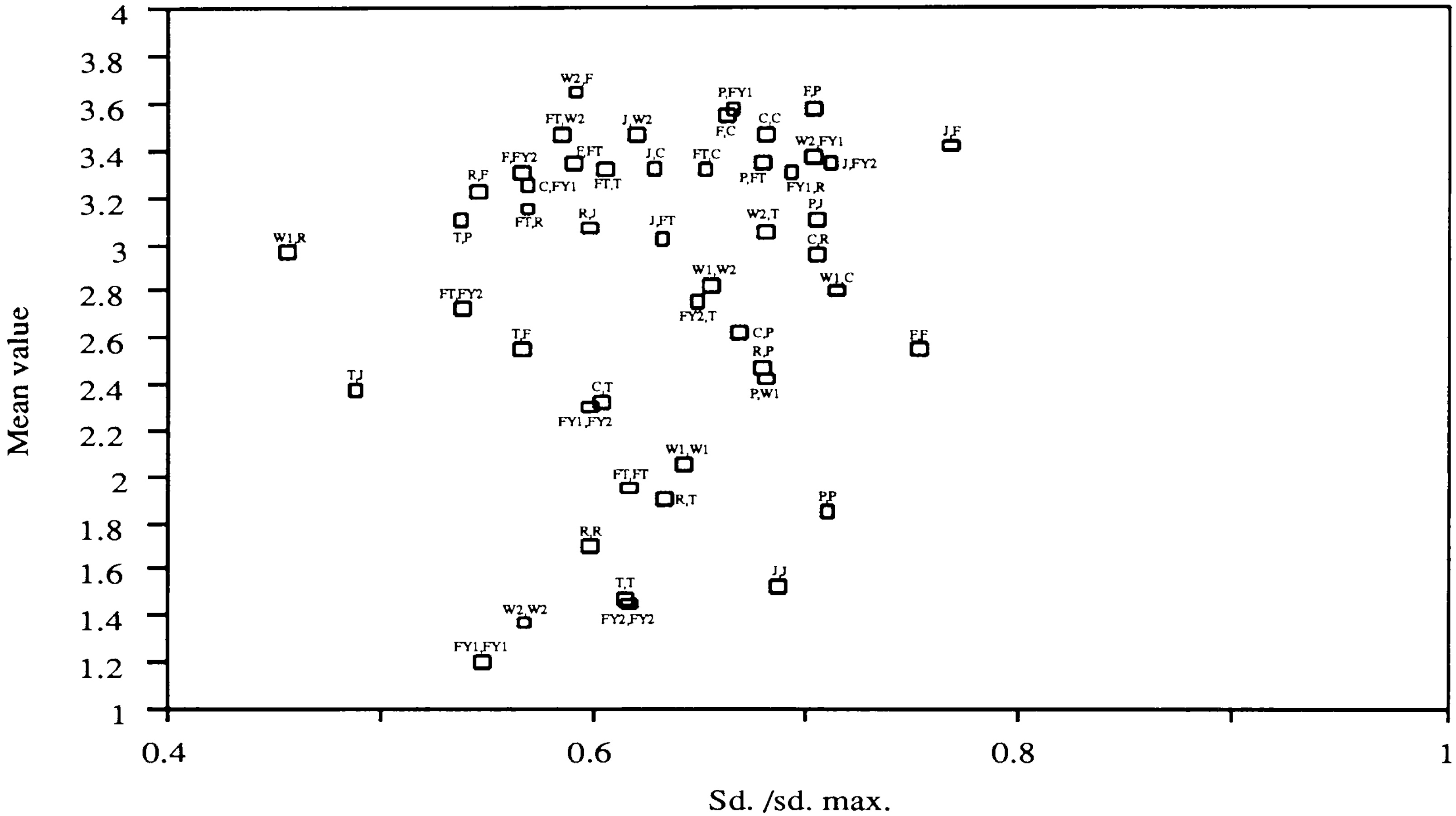
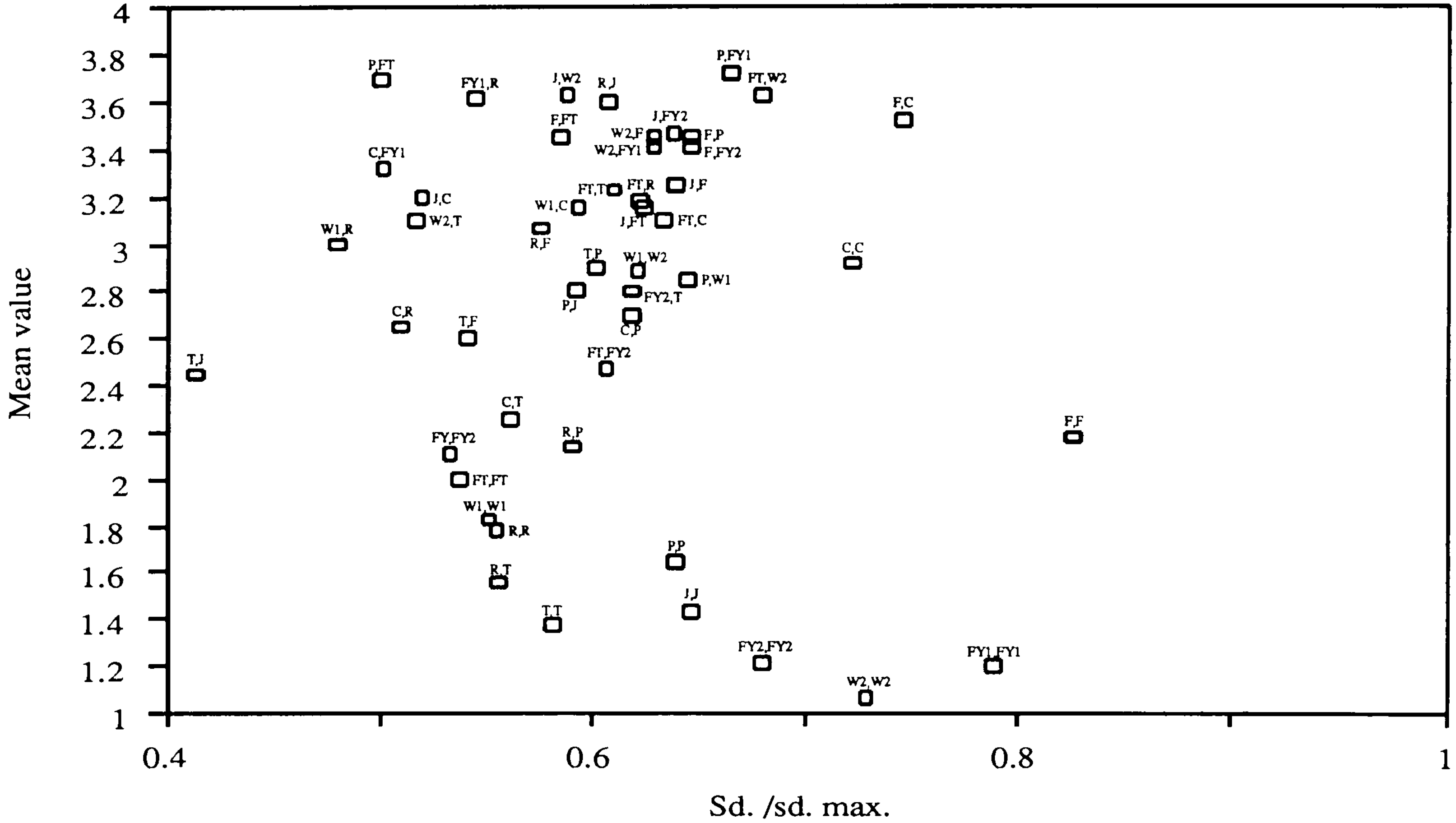


FIG. 8.11: MATCHING TASK 1. 12S' DATA.

Plot of mean versus sd./sd.max.



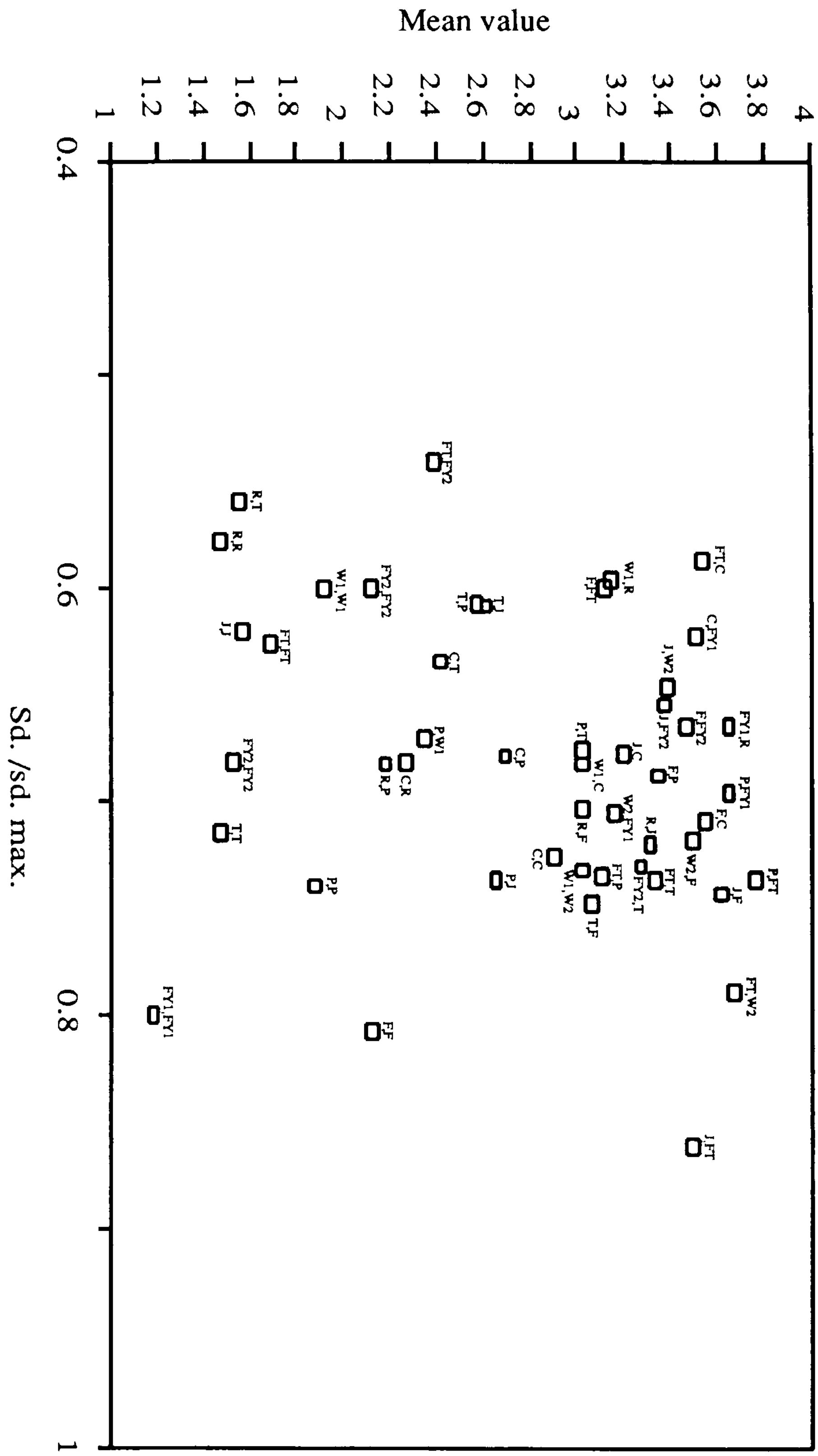
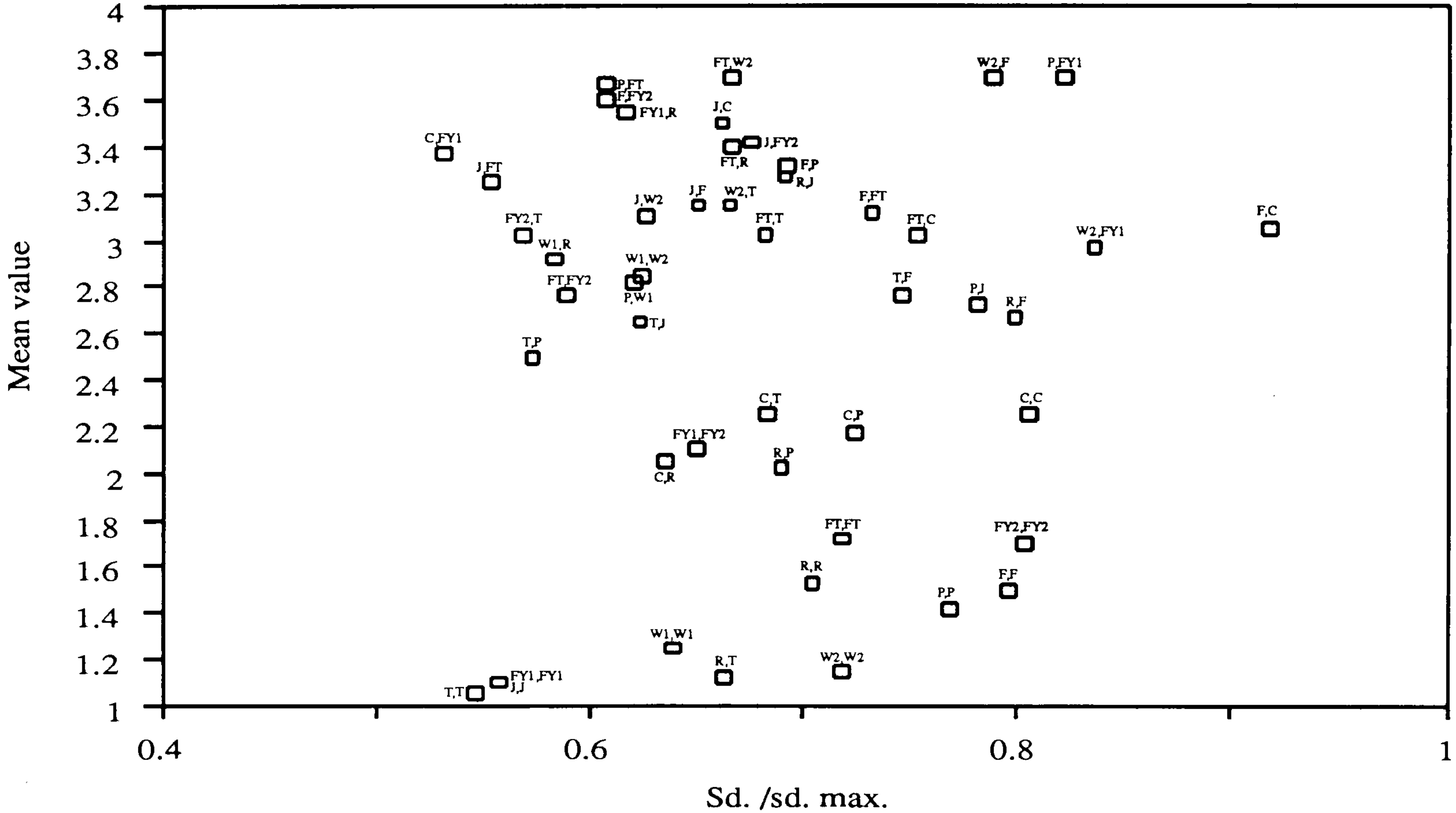


FIG. 8.12: MATCHING TASK 1. 14S' DATA.

Plot of mean versus sd./sd.max.

FIG. 8.13: MATCHING TASK 1. 16S' DATA.

Plot of mean versus sd./sd.max.



In order to assess whether there were any systematic differences in the variability of responses the mean values for each comparison were plotted against the maximum standard deviation for each age tested, as shown in figures 8.9 - 8.13. This type of analysis should identify the pairs of motions which subjects were unsure about, i.e. when there was no consensus among each age group about the reply. Further examination of these examples could suggest problems with with the choice of particular pictures for comparison i.e. illustrate methodological problems in the construction of the task or point to instances where the model is unclear.

8.5.1 Discussion of examples about which the children agreed and disagreed

The first interesting feature from this analysis is that the ten year olds showed the least variation of opinion, with no examples with a standard deviation/standard deviation greater than 0.8. The twelve year olds were similar with only one example above 0.8. One possible explanation for this result could be that at these ages the children have received little if any physics tuition and are subsequently more confident about their commonsense ideas.

There were no examples which the different age groups all differed strongly about and so there does not seem to be any methodological anomaly with any particular comparison. However, the seven and sixteen year olds disagreed amongst themselves most about the WALK FLY pair which had a standard deviation/standard deviation maximum of above 0.8 and both the twelve and fourteen year olds differed amonst themselves most strongly about the FALL identity comparison, again with a standard deviation/standard deviation maximum above 0.8.

There were more examples which different age groups agreed most strongly about i.e. those comparisons which all had a standard deviation/standard deviation maximum of 0.6 and below. All ages agreed most strongly about the WALK, ROLL comparison while the ten, twelve and fourteen year old agreed about ROLL, ROLL, FLY, FLYand FALL, FLOAT comparisons.

There appears not to be any systematic pattern from this set of data. This piece of anlysis instead, highlights the difficulties in constructing a test through representative examples.

8.6 POSSIBLE CAUSES OF MISMATCH BETWEEN EMPIRICAL DATA AND THEORETICAL PREDICTIONS

8.6.1 Introduction

The scatterplots have shown the cases where the theoretical and empirical data do not fit and also the examples which contribute most to the positive correlations. The following section examines certain comparisons in more detail and speculates about their contribution to the correlation. Two questions are asked to try and identify areas of mismatch between model and data. These are:

1. What distinctions may the children be making with the actual examples given which are not indicated by the model. (These ideas are drawn from informal discussions with the pupils after the task was administered).

2. Are there any particular problems with the examples chosen to represent the classes of FLOAT and CARRY? (since these comparisons contributed substantially to the mismatch between theory and data).

The correlations were recalculated after removing the problematic examples in each area to see more clearly how much these particular examples were contributing to the mismatch.

8.6.2 What distinctions could the pupils be making when comparing classes of motion which are not indicated by the theoretical model?

The possible distinctions to be considered are:-

a. Animate/inanimate -	The motion of an animate object was compared with that of an inanimate object.
b. Identical sources -	Two different stereotypical of motion motions were compared yet their sources of action were identical e.g. a horse was pushing a cart for the PUSH motion and a horse was jumping a fence for the JUMP motion. There is another possible interpretation for the similarity in children's responses for this example. One of the pictures chosen to represent JUMP was that of a horse jumping over a fence. The picture shows the horse landing and so this example could be interpreted more like a FALL motion.
c. Speed of motion -	An example illustrated a difference in speed between the compared motions which was not intended.
d. Direction of motion -	Some examples illustrated a difference in direction of motion that was not intended.

The specific examples for each of these distinctions is described in table 8.4 below. Table 8.5 illustrates the changes in correlations when these examples have been systematically removed.

Table 8.4: Paired examples of motions taken from Matching Task 1 which could have produced unpredicted results

EXAMPLE NUMBER	EXAMPLE NAME	PROBLEM PRESENTED BY THE COMPARISON OF THESE TWO PARTICULAR PICTURES
2	PUSH JUMP	Both sources of motion are HORSES.
	ROLL THROW	Both sources of people playing a game.
32	WALK WALK	SPEED difference.
15	JUMP JUMP	Movement in different directions.
24	WALK WALK	Movement in the downward direction for both examples.

Table 8.5: Correlations with theoretical position; comparison of 'identities' have been included after the removal of various examples

	Sevens Rank	Tens Rank	Twelves Rank	Fourteens Rank	Sixteens Rank	Mean Rank
No examples removed	0.680	0.620	0.655	0.750	0.720	0.698
Animacy	0.78	0.814	0.801	0.85	0.842	0.816
Horse ex.	0.716	0.627	0.639	0.773	0.739	0.721
Roll Throw	0.67	0.609	0.446	0.746	0.716	0.692
Speed ex.	0.665	0.602	0.637	0.739	0.707	0.683
Direction	0.677	0.611	0.641	0.752	0.710	0.689

The factor of animacy makes the most difference to the correlations. These results are discussed in more detail in chapter 9. The removal of the examples with identical sources of motion also improve the correlations, which suggests that the particular choice of examples interfered with the model's predictions. Identical causes of motion may decrease the predicted differences between many objects. However factors of speed and direction appear to make little difference to the correlations.

8.6.3 Are there particular problems with the examples chosen to represent CARRY and FLOAT?

The previous analysis indicated that both CARRY and FLOAT comparisons contributed to the mis-match between the models predictions and the empirical data. Table 8.5 illustrates the examples which could have contributed to this mis-match.

CARRY as a class of motion was not extensively tested in Matching Task 1. Only the two examples of CARRY-IN and CARRY-HELD were used and this selection could have produced an unfair test because the children were asked to compare two different types of CARRY and yet were expected to treat the examples as though they were equal.

The float examples all contained pictures of clouds. It was suspected that the motion of clouds in itself might be a difficult examples for the children to understand. Table 8.5 also reports these particular FLOAT examples found in Matching Task 1.

Table 8.6: Paired examples from Matching Task 1 which could have produced unpredicted results

EXAMPLE NUMBER	EXAMPLE NAME
3	CARRY ROLL
4	FALL CARRY
8	WALK 2 CARRY
10	CARRY PUSH
12	CARRY WALK
25	CARRY FLY
31	CARRY CARRY
35	CARRY THROW
39	JUMP CARRY
42	FLOAT CARRY
11	FLOAT FLOAT
23	PULL FLOAT
33	FLOAT WALK
42	FLOAT CARRY
47	FLOAT THROW

Tables 8.7 and 8.8 below report the Spearman correlations after the CARRY and the FLOAT comparisons were removed.

Table 8.7: Spearman correlations with theoretical position, plus identities; minus cloud examples. (Minus example numbers: 11, 23, 33, 42 and 47)

n = 44

	Sevens Rank	Tens Rank	Twelves Rank	Fourteens Rank	Sixteens Rank	Mean Rank
Theoretical Rank	0.679	0.602	0.635	0.718	0.703	0.679

Table 8.8: Spearman correlations with theoretical position, plus identities; minus CARRY examples

n = 39

	Sevens Rank	Tens Rank	Twelves Rank	Fourteens Rank	Sixteens Rank	Mean Rank
Theoretical Rank	0.687	0.681	0.689	0.759	0.748	0.715

There is an improvement in the correlations for all ages when the CARRY correlations were removed, which suggests that treating CARRY-IN and CARRY-HELD examples as equal did adversly affect the model's predictions. The correlations decrease when the FLOAT comparisons are removed, particularly so for the groups of fourteen year olds. This result suggests a problem with the theoretical status of FLOAT which is discussed in Chapter 11.

Table 8.9: Summary of Correlations with theoretical position; comparisons of 'identities' have been included after the removal of various examples

	Sevens Rank	Tens Rank	Twelves Rank	Fourteens Rank	Sixteens Rank	Mean Rank
No examples removed	0.680	0.620	0.655	0.750	0.720	0.698
Animacy	0.740	0.737	0.795	0.836	0.829	0.813
Horse ex.	0.716	0.627	0.639	0.773	0.739	0.721
Speed ex.	0.665	0.602	0.637	0.739	0.707	0.683
Direction	0.677	0.611	0.641	0.752	0.710	0.689
Float	0.679	0.602	0.635	0.718	0.703	0.679
Carry	0.694	0.695	0.691	0.763	0.757	0.720
Roll Throw	0.67	0.609	0.446	0.746	0.716	0.692

Table 8.9 summarises all the results and indicates which pieces of the model may be missing, namely a factor of animacy (see Chapter 9). The role of CARRY deserves further clarification and it appears to have been an unwise decision to treat CARRY-IN and CARRY-HELD motions as similar throughout Matching Task 1. The analysis also identified certain problems with a selection of representative examples of the stereotypes and that identical sources of motion take priority over the type of motion when a degree of difference is assessed. The notions of speed and direction require further investigation.

8.7 CONCLUSION

There are three main questions which need to be answered when the results from Matching Task 1 are considered. These are:

1. Do the children's responses match the theoretical predictions?

2. Are the responses similar for all the ages tested?

3. What features of the model still require further clarification?

(These questions are only briefly addressed in this chapter but are considered more fully in the light of the information gained from the other Matching Tasks, in Chapter 11.)

1. The correlations range from 0.62 -0.720 which suggest that children's responses can be predicted by the model. However the older children's replies fit the model better. The reasons why the seven year old responses may stand outside the majority of the data is discussed in more detail in Chapter 11.

2. There are differences betwen the responses with age with less difference between the 10/14 and 12/14 age groups. There were no systematic differences in the variability of responses with age (8.4.2) which could highlight any particular problem within the proposed theoretical model. Instead this result highlights the difficulties in constructing a test with representative examples.

3. The role of animacy, CARRY and FLOAT motions. require further clarification. Animacy and Carry are subjected to fuurther testing and the results are reported in chapters 9 and 10 respectively.

9. ANALYSIS OF MATCHING TASK 2 - A QUESTIONNAIRE TO INVESTIGATE THE ROLE OF ANIMACY IN A COMMONSENSE MODEL OF MOTION

This Chapter reports the results from Matching Task 2 and divides itself into five sections. 9.1 The **Introduction**, summarises the argument for devising a separate animacy task. 9.2 **Results**, reports the findings from the task and describes how a theoretical factor for animacy was devised. 9.3 **Further Analysis** reports an improvement in the Spearman correlations from Matching Task 1 with the addition of an animacy factor. **9.4 What is the consistency of response between the two age groups?**, discusses the differences in responses between the seven and sixteen year olds' data. 9.5 **Conclusion**, summarises the importance of the role of animacy in a commonsense account of motion.

9.1 INTRODUCTION

A more systematic analysis of the role of animacy required a separate matching task, which was devised as described in Section 7.3.5. The question which this task was designed to answer is whether subjects' judgements about the degree of difference between an inanimate and animate comparison varies systematically. If so not only would this result indicate that animacy is an important factor in a commonsense understanding of motion but if the degree of difference between an animate and inanimate motion could also be assessed, then this factor could be used to rework the empirical data from Matching Task 1 where animate/inanimate comparisons appeared. An improvement in the correlations, with the addition of an animacy factor, would be a further indication that the present version of the model is incomplete.

It was impractical to administer Matching Task 2 to all ages and so the animacy task was given to two groups of students only, the seven and the sixteen year olds. It was thought that if animacy is an important piece of the commonsense model of motion it should affect subjects' judgements at either end of the age spectrum and so the testing of only these two age groups should detect any animacy difference.

9.2 RESULTS

Table 9.1 illustrates the results obtained from Matching Task 2. The values shown are the mean scores of the seven and sixteen year old subjects tested. There were thirty children in each group. The test was scored in the same way as Matching Task 1. A value of 1 indicates that the pairs of motion were seen as very alike, 2 a bit alike, 3 a bit different and 4 very different.

There is a difference between the animate/inanimate comparison and both the animate/ animate and inanimate/inanimate comparisons for each class of motion tested except for FALLING. A possible explanation for the lack of any animacy effect for FALLING may be proposed using children's comments. The children during the piloting of the main Matching Task explained that living objects differed from non-living objects with respect to motion because the former are able to control their place and path of motion. These ideas make sense except when it comes to FALLING. But animate and inanimate objects have no control over FALLING motions once they have started. This proposal however requires further investigation.

9.2.1 Assessing an animacy allowance

In order to assess the importance of a difference between animate and inanimate motion the mean of inanimate/inanimate and animate/animate scores was taken from the animate/ inanimate score as shown in Table 9.2 below. The mean difference in animacy (for all the motions except FALL and PUSH) see Table 9.2 is 1.28. It therefore seems reasonable to suggest that a factor of 1.0 can be used to assess the difference between two distinct sources of motion with respect to animacy.

The FALL and PUSH comparisons were ignored when calculating the animacy allowance. The reasons for ignoring FALL motions are as given in 9.2 while the PUSH comparisons were omitted because the moving object in all the PUSH motions was inanimate. This means that it was only the source of motion that changed in respect to animacy with the PUSH PUSH comparison. Therefore this example provides a very rough test of whether the animacy difference is provoked by the moving object itself or the source of motion being alive. It appears that for our purposes we should only apply the animacy allowance to examples where the moving object is animate.

Table 9.1: Mean value of similarity for each comparison from each age group per class of motion

CLASS OF MOTION

Examples Compared	CARRY		PUSH		FLY		JUMP	
	Mean Score 7 Year Olds	Mean Score 16 Year Olds	Mean Score 7 Year Olds	Mean Score 16 Year Olds	Mean Score 7 Year Olds	Mean Score 16 Year Olds	Mean Score 7 Year Olds	Mean Score 16 Year Olds
II	2.9	1.6	2.5	2.3	1.8	2.0	2.48	2.1
AA	3.24	1.4	2.7	2.1	1.95	1.1	2.29	1.4
AI	3.81	3.3	2.8	1.7	3.24	3.2	3.05	2.7

CLASS OF MOTION

	FALL		THROW		WALK		ROLL		FLOAT	
	Mean Score 7 Year Olds	Mean Score 16 Year Olds	Mean Score 7 Year Olds	Mean Score 16 Year Olds	Mean Score 7 Year Olds	Mean Score 16 Year Olds	Mean Score 7 Year Olds	Mean Score 16 Year Olds	Mean Score 7 Year Olds	Mean Score 16 Year Olds
II	2.7	1.2	2.29	1.1	1.52	1.1	2.43	1.8	3.00	1.6
AA	3.1	1.9	1.95	1.5	3.38	1.8	1.76	1.2	3.00	1.3
AI	2.62	1.44	3.24	2.5	3.57	3.24	3.3	3.3	3.67	3.2

* I = Inanimate A = Animate

Table 9.2: Differences between the animate/inanimate score and the mean of the animate/animate and inanimate/inanimate values

CLASS OF MOTION

CARRY		FLY		JUMP	
7 YEAR OLD A/I DIFF-ERENCE	16 YEAR OLD A/I DIFF-ERENCE	7 YEAR OLD A/I DIFF-ERENCE	16 YEAR OLD A/I DIFF-ERENCE	7 YEAR OLD A/I DIFF-ERENCE	16 YEAR OLD A/I DIFF-ERENCE
0.74	1.8	1.37	1.65	0.67	0.95

CLASS OF MOTION

THROW		WALK		ROLL		FLOAT	
7YEAR OLD A/I DIFF-ERENCE	16 YEAR OLD A/I DIFF-ERENCE	7 YEAR OLD A/I DIFF-ERENCE	16 YEAR OLD A/I DIFF-ERENCE	7 YEAR OLD A/I DIFF-ERENCE	16 YEAR OLD A/I DIFF-ERENCE	7YEAR OLD A/I DIFF-ERENCE	16YEAR OLD A/I DIFF-ERENCE
1.12	1.2	1.12	1.79	1.21	1.8	0.67	1.75

I = Inanimate A = Animate

9.2.2 Adjusting the theoretical predictions with respect to the animacy factor

Each example from matching task 1 was carefully examined to see if there was an animacy difference between the pairs of moving objects. Eighteen examples were identified in all and a factor of 1 was added to the theoretical differences for these examples. The eighteen changed pairs are identified in Table 9.3 below.

Table 9.3: The pairs of motion which were given an animacy allowance of one to their theoretical score

Example Number	Example Name	New Theoretical Score
20	FLY1 FLY2	2
27	WALK1 WALK2	2
31	CARRY CARRY	2
38	FALL FALL	2
19	WALK2 FLY1	3
28	THROW JUMP	3
43	PUSH WALK1	3
49	FALL FLOAT	3
7	PUSH FLY1	4
9	JUMP FLY2	4
15	JUMP FALL	4
21	JUMP WALK2	4
39	JUMP CARRY	4
44	JUMP FLOAT	4
48	ROLL JUMP	4
25	CARRY FLY1	5
34	FALL PUSH	5
50	FLY1 ROLL	5

This change gave rise to a new theoretical ranking with which the empirical data could be compared. This new ranking is shown in appendix VII.

9.3 FURTHER ANALYSIS

The empirical data was then compared to the revised theoretical scores. The results of the recalculation of Spearman's coefficient of rank correlation are given in tables 9.4 and 9.5 below and are discussed in conjunction with the new scatter plots.

9.3.1 How are the Spearman Correlations affected by an animacy allowance?

At each age, the inclusion of an animacy allowance improves the correlations between theoretical and empirical rankings of comparisons. The lowest correlation (is age ten) is now comparable with the highest previously obtained. The correlations are generally rather large. It remains the case that correlations for older children are higher than those for the younger ones.

Table 9.4: Correlations with and without animacy allowance; ('identities' included)

n = 49

	Sevens Rank	Tens Rank	Twelves Rank	Fourteens Rank	Sixteens Rank	Mean Rank
No Animacy Allowance.	0.680	0.620	0.655	0.750	0.720	0.698
With Animacy Allowance	0.740	0.737	0.795	0.836	0.829	0.813

Table 9.5 reports the correlations with an animacy allowance when the identities are removed. There is an improvement at each age with the inclusion of an animacy allowance. The seven yearolds' correlation is much lower than the others and stands alone. It could be a methodological and/or a theoretical problem that the seven year olds' correlation is different from the others. The seven year olds may focus upon details in the pictures which do not necessarily provide relevant information to the problem in question. When some

seven year old children were asked why certain motions were different to others their replies suggested that they tended to focus upon mechanisms of motion and not the source of movement e.g. a go cart moves with its wheels and a horse moves with its legs. It could be suggested that internal and external sources of effort have not yet become generalised see 11.2. These results draw attention to the fact that it is difficult to devise a paper and pencil task which is suitable for both young primary and senior secondary pupils.

Table 9.5: Correlations with and without animacy allowance, comparison of different examples of the same class have been omitted

n = 36

	Sevens Rank	Tens Rank	Twelves Rank	Fourteens Rank	Sixteens Rank	Mean Rank
No Animacy Allowance.	O.292	O.318	O.278	O.513	O.406	O.344
With Animacy Allowance.	0.399	0.517	0.561	0.665	0.623	0.579

9.3.2 Scatterplot of mean score for total population sampled against the theoretical prediction

The general shape of the scatter plot of mean results for all ages as shown by Figure 9.1 is that of a curve which peaks at a ranked theoretical score of 4 and then falls away to a ranked theoretical score of 5. The animacy allowance when added to the three pairs which already were scored as very different i.e. with a score of 4 gives them a score of 5 and puts them outside the range which the children could actually indicate during the test. The pupils in practice were not permitted to distinguish between very different and very very different as these new theoretical scores suggest. These three examples of FLY, ROLL; FALL, PUSH; and CARRY, FLY1 were predicted by the model as the most different yet were not seen to be the most different by the children.

The identitites are now grouped together more closely than they were without the addition of an animacy allowance (see Figure 7.3). It is interesting to note that the inanimate comparisons of WALK are seen as more similar than the animate comparisons of WALK. The FLY comparisons are surprisingly the other way around. A possible explanation for the WALK result is that some of the seven year old pupils did differentitate more strongly between the motion of humans from that of other animals.

The examples which had a ranked theoretical value of 2.0 fall into three distinct groups as before but now consist of different examples than found in Matching Task 1. The ROLL, THROW comparison as before, is seen by the pupils as more similar than expected. It at first seems rather puzzling that ROLL and THROW motions should be seen as more similar than the comparison of similar examples of FLOAT, WALK (animate), PUSH and ROLL. The reason could lie with problems associated with the theoretical status of FLOAT, and notions of control associated with human movement and the design of the matching task itself. The questionnaire required the pupils to focus upon the reasons why the two things move and it could be that with ROLL and THROW the pupils focussed only on the start of these motions, (see section 8.4.3). They both require an external source of motion and the ongoing motion is the same. It could be suggested that in this instance differences of support are ignored by the children when the reason or cause of these two types of motion are considered.

The CARRY, CARRY and WALK1, WALK2 comparisons even with the addition of an animacy allowance are much higher than predicted by the theory. The latter have already been discussed but CARRY is a complex motion and the results from its separate questionnaire are discussed in chapter 10.

Most of the examples with a ranked theoretical score of 3 fit the theoretical predictions rather better with the addition of an animacy allowance. Except for the FALL FLOAT comparison and a group of CARRY comparisons. The FALL, FLOAT comparison is much higher than predicted by the model. The theoretical position suggested that FALLING and FLOATING actions were similar in one way and that was they both required no effort to make them move. The pictures used for these comparisons were those of a burglar falling from a

FIG. 9.1 SCATTERPLOT OF MEAN SCORE AGAINST THEORETICAL SCORE OF FIRST FORMALISED VERSION OF THE MODEL, PLUS ANIMACY ALLOWANCE.

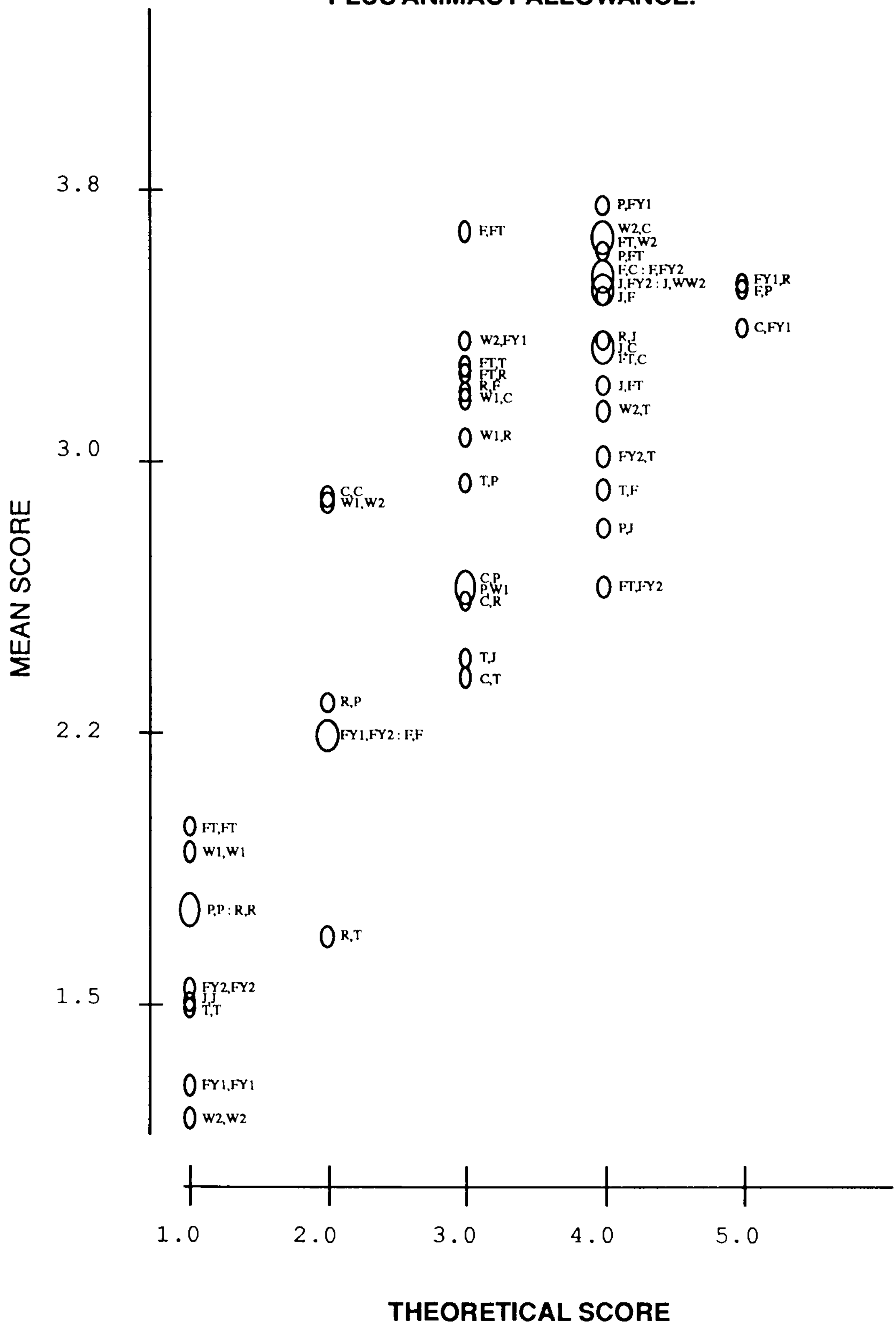


FIG. 9.2 SCATTERPLOT OF SIXTEENS' MEAN SCORE AGAINST THEORETICAL SCORE OF FIRST FORMALISED VERSION OF THE MODEL, PLUS ANIMACY ALLOWANCE.

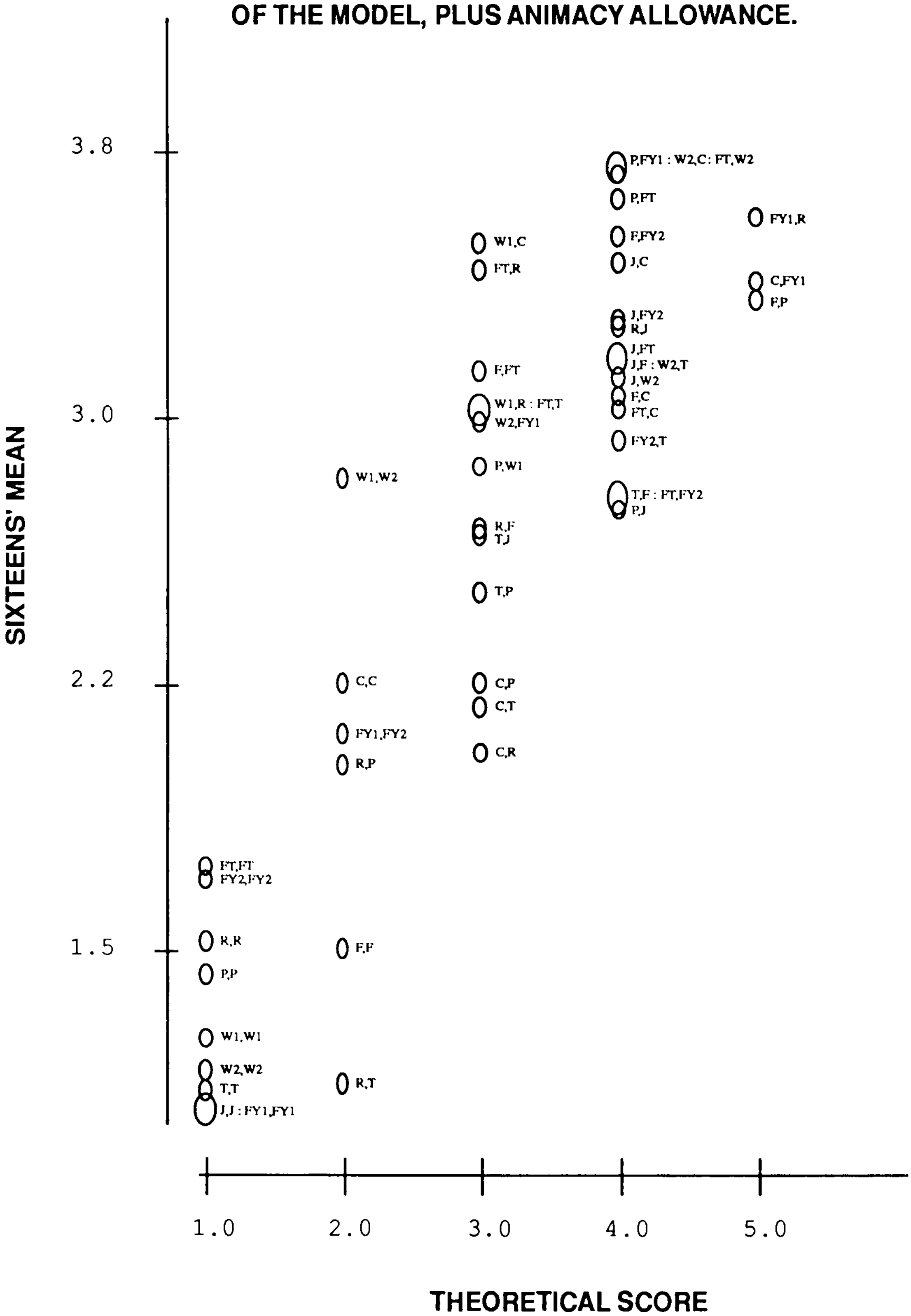


FIG.9.3 SCATTERPLOT OF FOURTEENS' MEAN SCORE AGAINST THEORETICAL SCORE OF FIRST FORMALISED VERSION OF THE MODEL, PLUS ANIMACY ALLOWANCE.

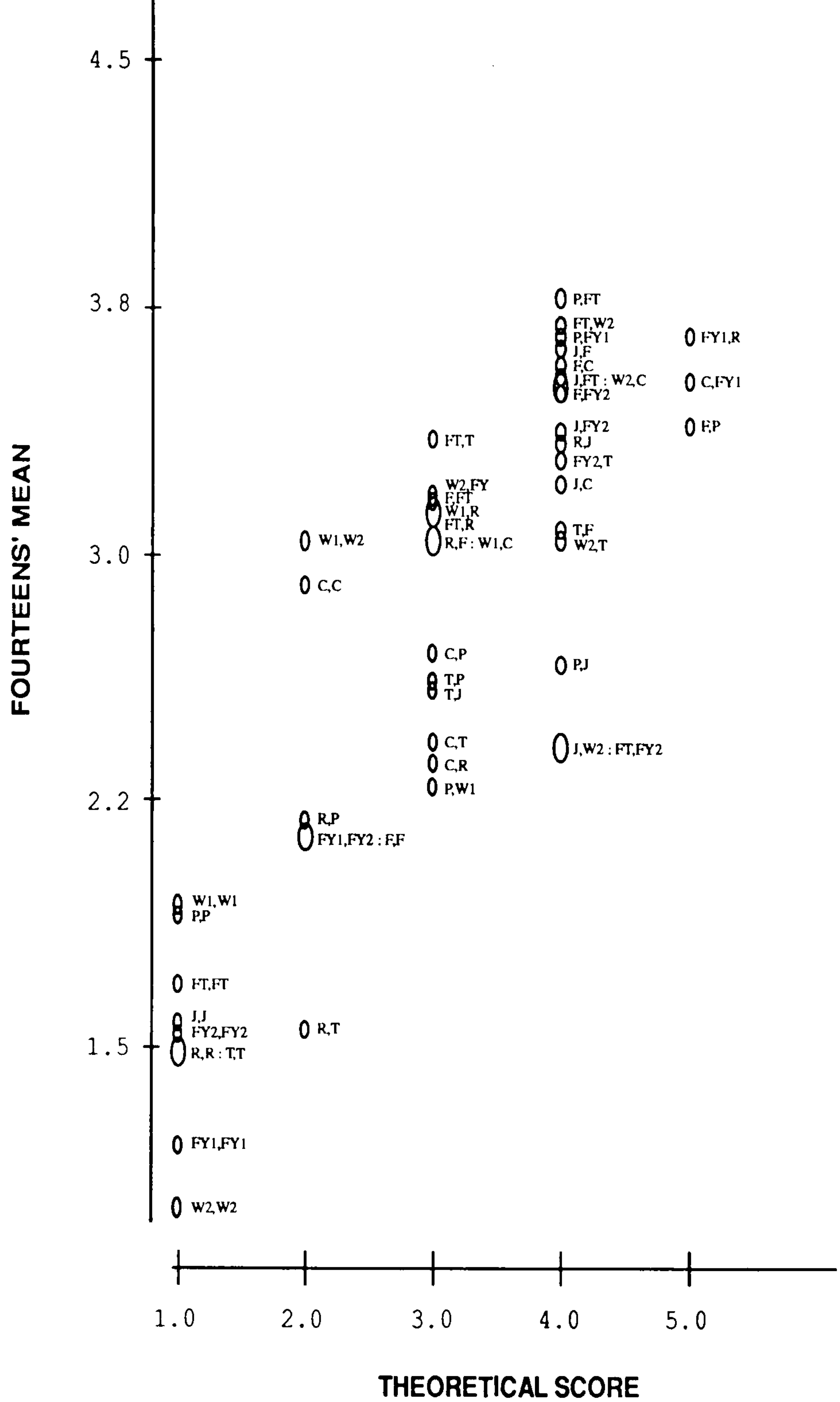


FIG.9.4 SCATTERPLOT OF TWELVES' MEAN SCORE AGAINST THEORETICAL SCORE OF FIRST FORMALISED VERSION OF THE MODEL, PLUS ANIMACY ALLOWANCE.

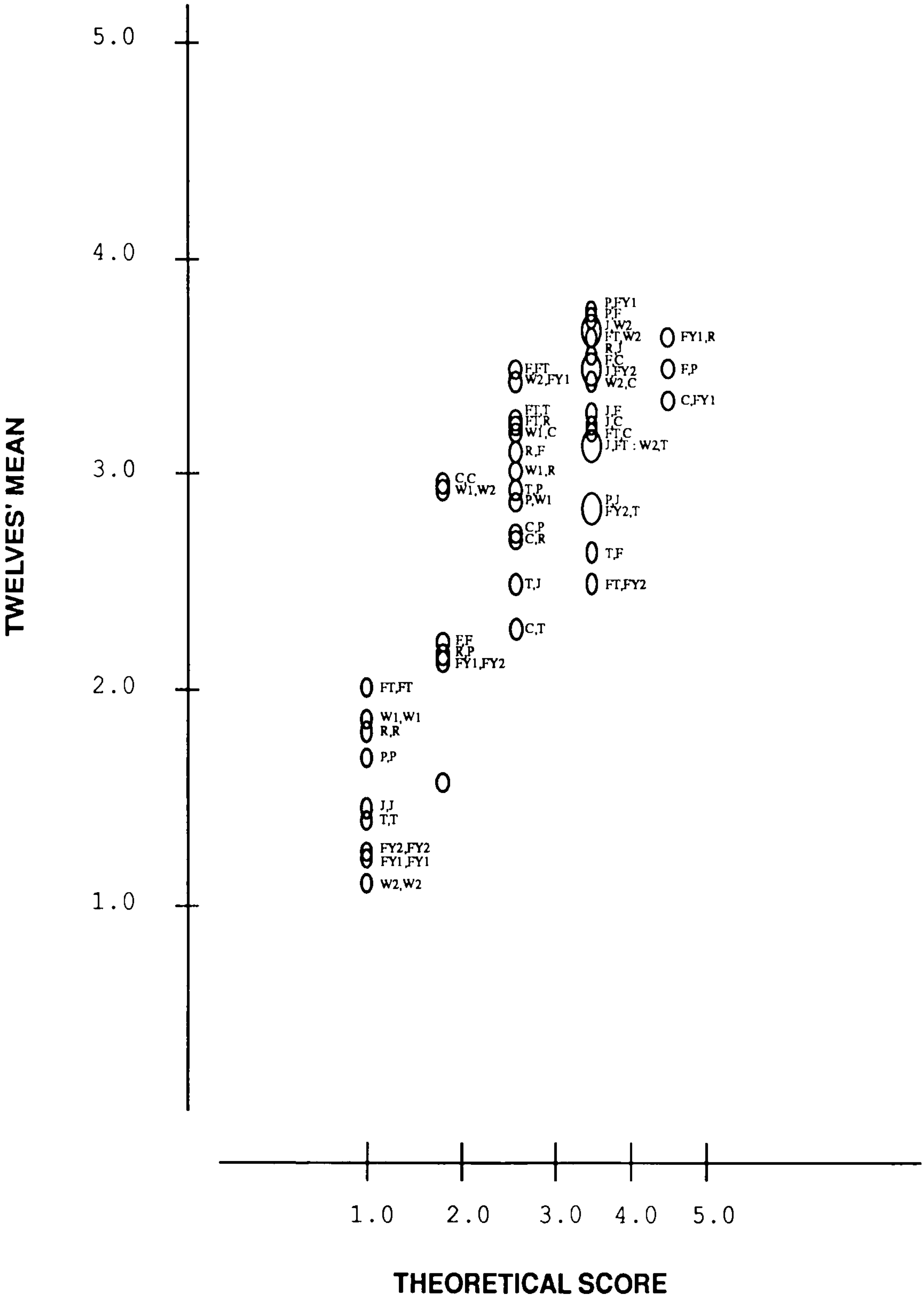


FIG.9.5 SCATTERPLOT OF TENS' MEAN SCORE AGAINST THEORETICAL SCORE OF FIRST FORMALISED VERSION OF THE MODEL, PLUS ANIMACY ALLOWANCE.

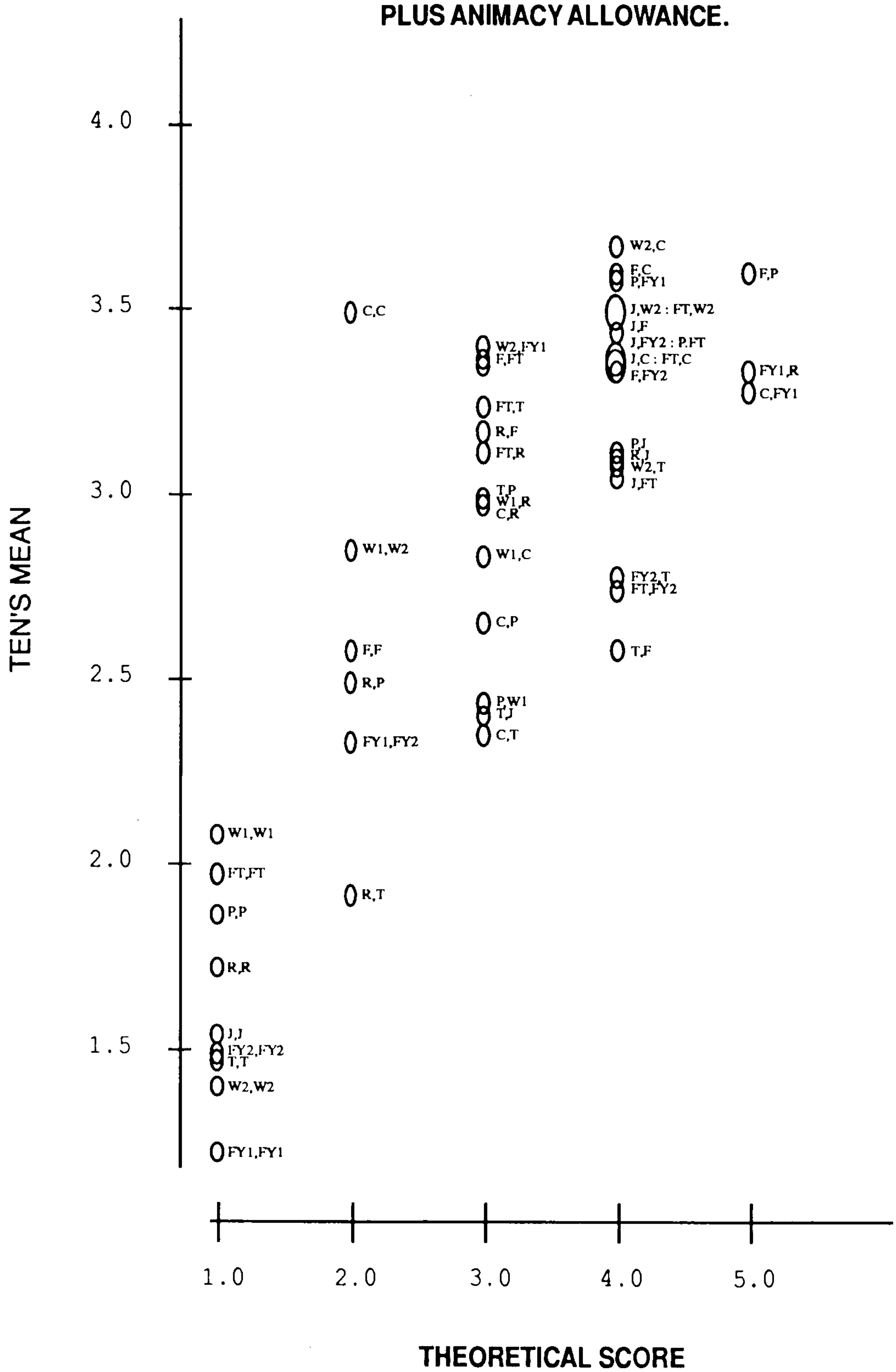
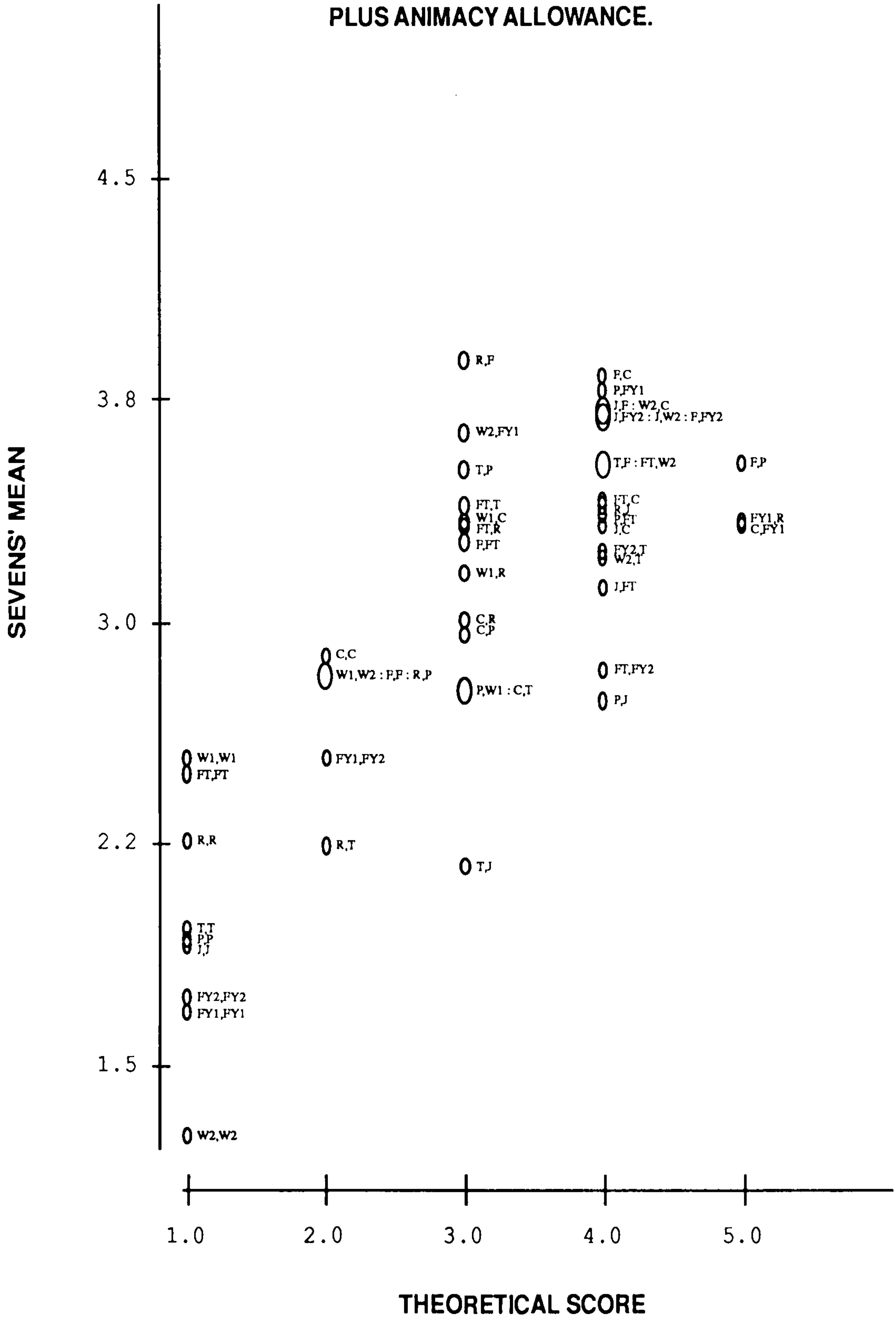


FIG.9.6 SCATTERPLOT OF SEVENS' MEAN SCORE AGAINST THEORETICAL SCORE OF FIRST FORMALISED VERSION OF THE MODEL, PLUS ANIMACY ALLOWANCE.



drainpipe and a balloon floating in the air. The latter example however requires closer inspection and it could be that the subjects believe that the balloon moves because of the air and so does require a source of effort. This unusual result could therefore be a methodological problem with the definition of float.

There were five examples which were seen as more similar than expected. These were:-

CARRY, PUSH
PUSH, WALK
CARRY, ROLL
THROW, JUMP
THROW, CARRY.

Three of these are CARRY examples and the theoretical problems associated with CARRY are discussed in Chapter 10. It could be with the THROW JUMP comparison that these two motions are seen as more similar because they are both objects being thrown into the air. With throwing the object is given effort from by an external agent while with jumping the effort is internal. The suggestion is here that JUMPING is perceived by the children more like a THROW type motion than expected. This point requires further investigation.

There is a greater separation between the examples with a ranked theoretical score of 4 when an animacy allowance is added. The pairs of comparisons which were seen as more similar than expected are identical to those shown in Figure 7.3 without the additon of an animacy allowance.

9.3.3 Comparison of twelve, fourteen and sixteen year olds scatterplots with mean scatterplot

These all exhibit a similar shape to the plot of the mean values. The fourteen year old curve differed the most from the mean plot with the PUSH JUMP, JUMP WALK2 and FLOAT FLY2 comparison seen as more similar than predicted. (These comparisons had a ranked theoretical score of 4). However other pairs of motions were seen as greater or less different than predicted by the theoretical model and included CARRY, FLOAT, THROW and JUMP motions. This results perhaps raises questions about the theoretical status of these motions, it is discussed in cahpter 11.

See Figures 9.4, 9.5 and 9.6.

9.3.4 Comparison of ten year old scatterplot with mean scatterplot

The general shape of the seven year old scatterplot is the same as depicted by the mean scatterplot if the CARRY, CARRY comparison is ignored. This value is unusually high for the ten year olds.

See Figure 9.4.

9.3.5 Comparison of seven year old scatterplot with mean scatterplot

The general shape is similar to that of mean scatterplot but the high point is found at theoretical score 3 rather than score 4. It is the ROLL, FLOAT value which is very high here and throws out the general pattern. The THROW JUMP comparison in this column is also exceptionally low.

See Figure 9.3.

9.3.6 Summary

There is a better match between the mean scatterplot and that of the theoretical plot when an animacy allowance is added because:-

1. The identities now form a closely knit group, and

2. There is a greater separation between the examples predicted as not identical.

The scatterplots of the seven and ten year olds showed more difference from the mean plot than the graphs of the secondary school pupils. The recurring difference of the seven year old data from the older children is discussed in section 11.2.

The ROLL and THROW comparison was seen as more similar then predicted and points to a methodological problem in the choice of pictures used to represent these motions which perhaps caused pupils to focus only on the start of these motions, (see 9.3.2). Even with the addition of an animacy allowance there appear to be theoretical problems with CARRY, FLOAT, JUMP, THROW and ROLL comparisons. These issues are discussed in Chapter 11.

9.4 WHAT IS THE CONSISTENCY OF RESPONSE BETWEEN THE TWO AGE GROUPS FOR MATCHING TASK 2?

As before, the Wilcoxon signed ranks test was used to see:-

1. Whether the seven and sixteen year olds identified the pairs of motions similarly, and

2. Whether the variability in the responses was the same for each group tested.

A T value of 9 was obtained when each comparisons given by the children of different ages were compared by rank order. This value of T falls well outside the 1% significance level, supporting the view that there are real differences between the two age groups in how they judged the differences between examples. (For n = 28, 95% limits for T are 105.8 - 272).

A T value of 43 was calculated when the variability of judgements between the ages was compared. This was computed as described in section 8.3. Again the value of T lies outside the 1% significance level, supporting the view that there are real differences between the two ages in the variability of the judgements. (For n = 28, 95% limits for T are 105.8 - 272).

Although there is a big difference in the variability of responses it would be interesting to see if the two ages agreed and disagree about any of the same comparisons. These examples,

FIG.9.7: MATCHING TASK 2, 7'S DATA.

Plot of mean versus sd./sd.max.

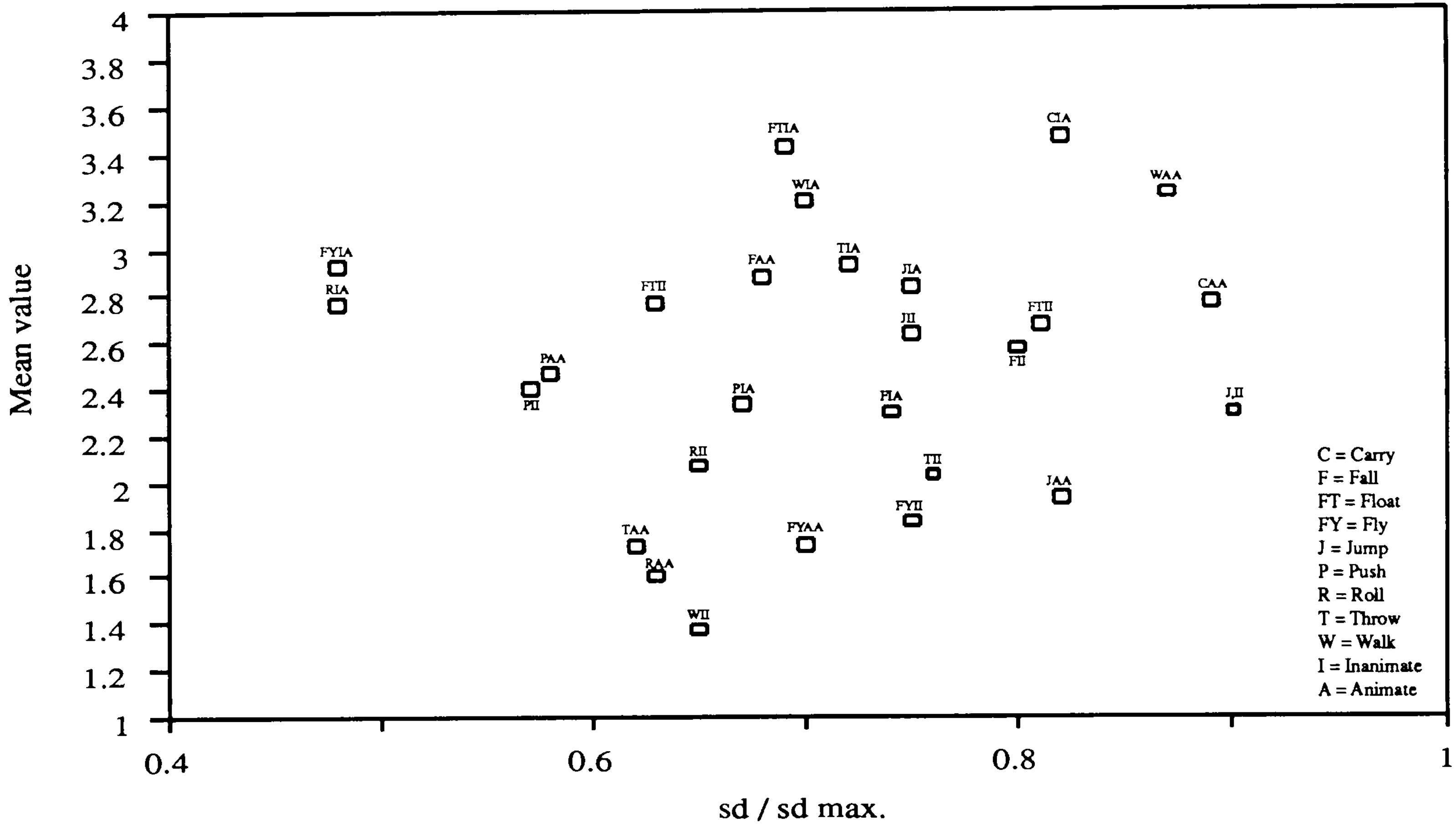
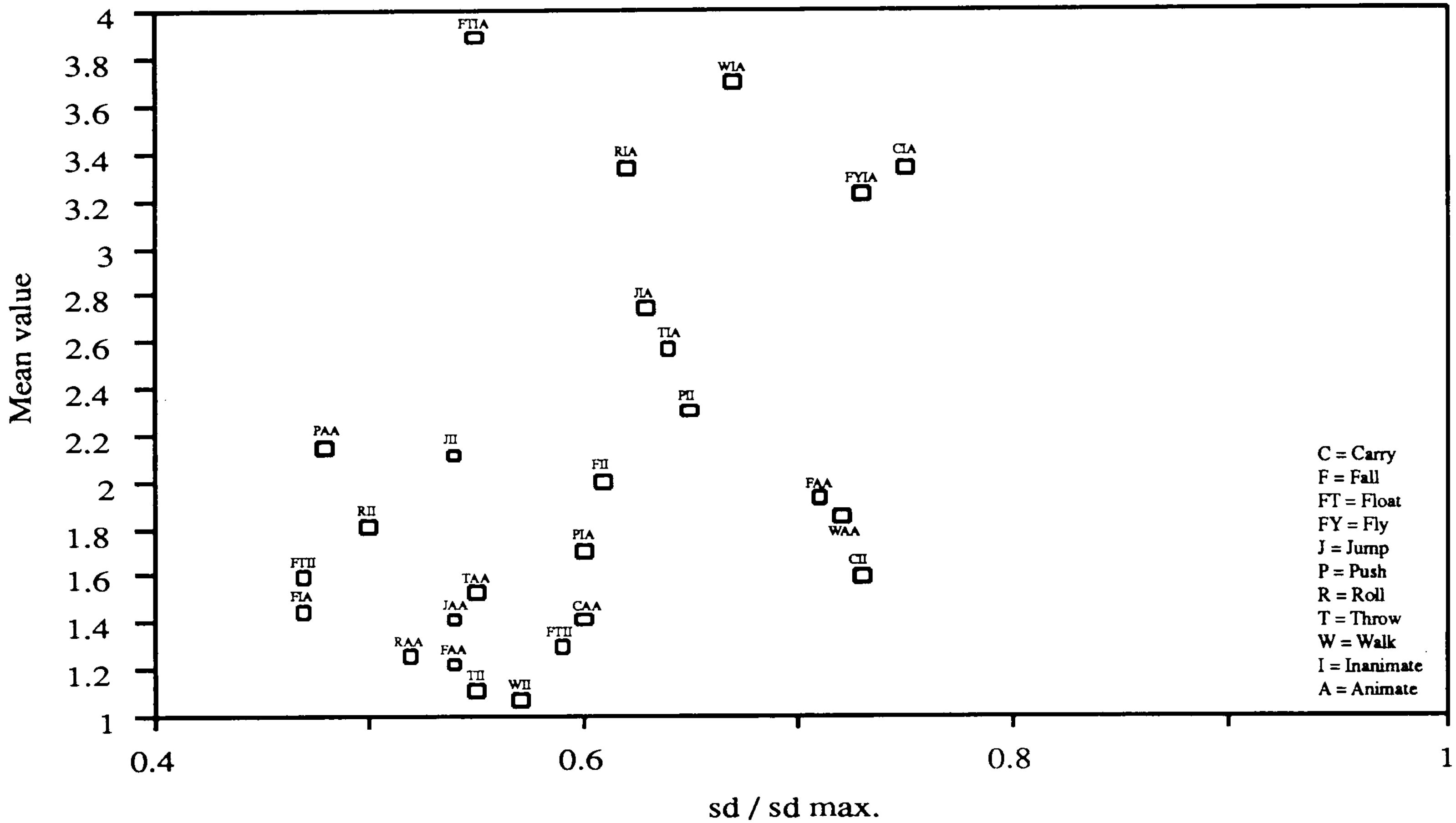


FIG.9.8: MATCHING TASK 2, 16'S DATA.

Plot of mean versus sd./sd.max.



if present, may identify methodological problems in the construction of the task. This information was obtained by plotting the mean values against the maximum standard deviation for the two age groups tested.

Both age groups agreed most strongly about the PUSH (animate/ animate) comparison. There were two examples which the different age groups all differed most strongly about those being the inanimate/animate CARRY pair and the WALK inanimate/animate comparisons. The CARRY comparisons were perceived to be more different than expected in Matching Task 1. Those results highlighted the problem of in trying to pick identical examples of CARRY motions when the model itself predicts there are differences within the CARRY paradigm. The two graphs (Figures 9.7 and 9.8) however do show that there was a greater variability in responses with the seven year olds. This result emphasises the point raised in section 9.3 about devising a test suitable for such a wide age range of pupils especially where the younger ones were observed to focus on particular details of the picture examples. However, the difference between the seven year old data and the rest is an important issue which is discussed in chapter 11.

9.5 CONCLUSION

The systematic testing of inanimate and animate comparisons indicated that children do consider animacy to be an important distinguishing feature as regards to motion. An assessment of this degree of difference was calculated and applied to the model.

A better match has been found between the empirical data collected in Matching Task 1 and the theoretical predictions. The correlations improved from about 0.6 to nearer to 0.8. However, the predictions were still rather better for the older children while the younger ones pay more attention to specific details and vary more in their judgements. The discrepant pairs suggest that animacy is linked to **control** or **accident**. In conclusion, the results suggest that animacy is a factor which should no longer be neglected by the model and should be considered as one of the essential elements of a commonsense understanding of causes of motion.

10. ANALYSIS OF MATCHING TASK 3 - A QUESTIONNAIRE DESIGNED TO INVESTIGATE THE ROLE OF CARRY IN A MODEL OF COMMONSENSE CAUSES OF MOTION

This chapter reports the results of Matching Task 3. 10.1 **Introduction**, describes how the task was designed to systematically test the model's predictions about CARRY motions. 10.2 **Summary of results** reviews the main results. 10.3 **Analysis of CARRY identities** specifies the results from these types of comparisons, while 10.4 **Comparison of different CARRY motions** reports the results from further comparisons. 10.5 **How similar are the CARRY comparisons to the equivalent stereotypical single motion comparisons?** describes the results when data collected from this test is compared with the equivalent results from Matching Task 1. 10.6 **What is the consistency of response?** discusses the difference between the seven, twelve and sixteen year old data. 10.7 **Conclusion**, summarises what has been learnt about the theoretical status of CARRY.

10.1 INTRODUCTION

CARRY was tested in the same way as the other sterotypical motions in Matching Task 1 (see chapter 8) in order to systematically examine all nine motions in a similar way. The results of Matching Task 1 showed that the CARRY motions differed more from one another than the other matched pairs, which indicates that its role requires further clarification.

CARRY's definition as a compound motion raises interesting questions about how people in practice actually do view the movement of a carried object. Will the carried object be seen as quite separate from the carrier or is it perceived as part of the carrier's motion? The model suggests that the carried object will be seen as part of the carrier's motion but that this will also be dependent upon the type of attachment between carried and carrier. In fact will objects that are carried in different ways e.g. HELD BY or CARRIED IN be seen as different? These are not such trivial questions as might appear: the nature of objects themselves may depend on such features as parts of an object being recognised as one whole unit and not seen as separate pieces. It would be interesting to explore this idea, albeit in a very preliminary way, with a Matching Task which investigates the motion of carried objects.

The main purpose of this chapter is to see if the model's predictions about "CARRY-type" motions are correct by answering the questions below. This is possible because the test was constructed in a systematic way to include the comparisons described below (see 7.3.6).

1. Are the carry motion identities seen as similar?
   (Compare Carry X with Carry X).

2. Are CARRY-IN motions seen differently from CARRY-HELD motions?
   (Compare Carry-In X with Carry-Held X).

3. Is the movement of a carried object which is being flown, pushed or floated etc. seen as similar to the corresponding simple motions of flying, pushing or floating etc.
   (Compare Carry X with X).

4. Are the responses between the age groups similar?

It is possible to check these findings in another way by comparing the results from this test with the results from Matching Task 1. In this way one can ask another important question. Are CARRY motions compared in a similar way to their equivalent single stereotypical motions, e.g. is a CARRY PUSH, CARRY FLY comparison judged in a similar way as a single PUSH FLY pair of motions?

CARRY as a compound motion deserves special attention and the results of its systematic testing are reported in order to clarify the role of CARRY in a model of commonsense ideas about causes of motion.

10.2 SUMMARY OF RESULTS

The overall picture emerging from this test is illustrated by figure 10.1. The results on the whole tend to match the model's predictions about CARRY motions.

These can be summarised as follows:-

1. The motion of carried object is seen as similar to the motion of its carrier. CARRY X CARRY X comparisons were seen as similar to CARRY X X pairs and there was no significant variation between the ages tested.

2. CARRY-IN pairs are seen as similar to one another but pairs of CARRY-IN, CARRY-HELD examples are viewed as rather different - supporting a view proposed by the model that the two types of CARRY are different. It might be supposed that the CARRY-IN attachment is seen as more permanent and stable than a CARRY-HELD link. This would mean that all the pieces of a CARRY-IN motion are interpreted more as the movement of only one object. Again there is no significant difference between the responses of all the ages tested.

3. The prediction that a carried object's motion should be seen as similar to the equivalent motion of its carrier was also confirmed by comparing the data from Matching Task 1 with Matching Task 3. Some differences in responses are found between the ages.

10.3 ANALYSIS OF CARRY IDENTITIES

10.3.1 Comparison of CARRY-IN motions

The examples are recognised as similar to each other by pupils of all ages. These pairs of motions are seen as more similar to each other than the rest of the CARRY identity comparisons. (Compare table 10.1 with tables 10.2 and 10.3).

For this set of comparisons the FLOAT difference between identities was larger than predicted by the model and bigger than the other set of comparisons in this group. The pictures used to represent FLOAT were passengers being transported in a hot air balloon and passengers travelling in a glider. It could well be that the pupils perceived the glider as an ordinary aeroplane flying under engine power. The comparison would then be between a CARRY FLOAT and a CARRY FLY rather than just CARRY FLOAT comparisons. The stereotypical motion Float and the examples chosen to represent this motion questions the previous theoretical conception of Float, especially as difficulties arose with this motion in Matching Task 1 also. It is proposed in chapter 12 that there are two possible interpretations for Float.

Table 10.1: Comparison of Identities of CARRY-IN

Example Number	Example Name	Sevens' Mean	Twelves' Mean	Sixteens' Mean
4	CARRY FLY AND CARRY FLY	1.63	1.21	1.22
10	CARRY FLOAT AND CARRY FLOAT	1.67	1.83	1.81
27	CARRY WALK AND CARRY WALK	1.23	1.28	1.06
31	CARRY PUSH AND CARRY PUSH	1.57	1.45	1.25
38	CARRY FALL AND CARRY FALL	1.40	1.72	1.41

10.3.2 Comparison of CARRY-IN and CARRY-HELD motions

The model suggests that CARRY-IN and CARRY-HELD pairs should be seen as different from one another. Therefore CARRY-IN/HELD comparisons were made for the five classes of motion investigated in this task. The results illustrated by Figure 10.1 and Table 10.2 suggest that the pupils do distinguish between CARRY-IN/HELD motions and they are seen as different.

MEAN VALUES OF CARRY COMPARISONS

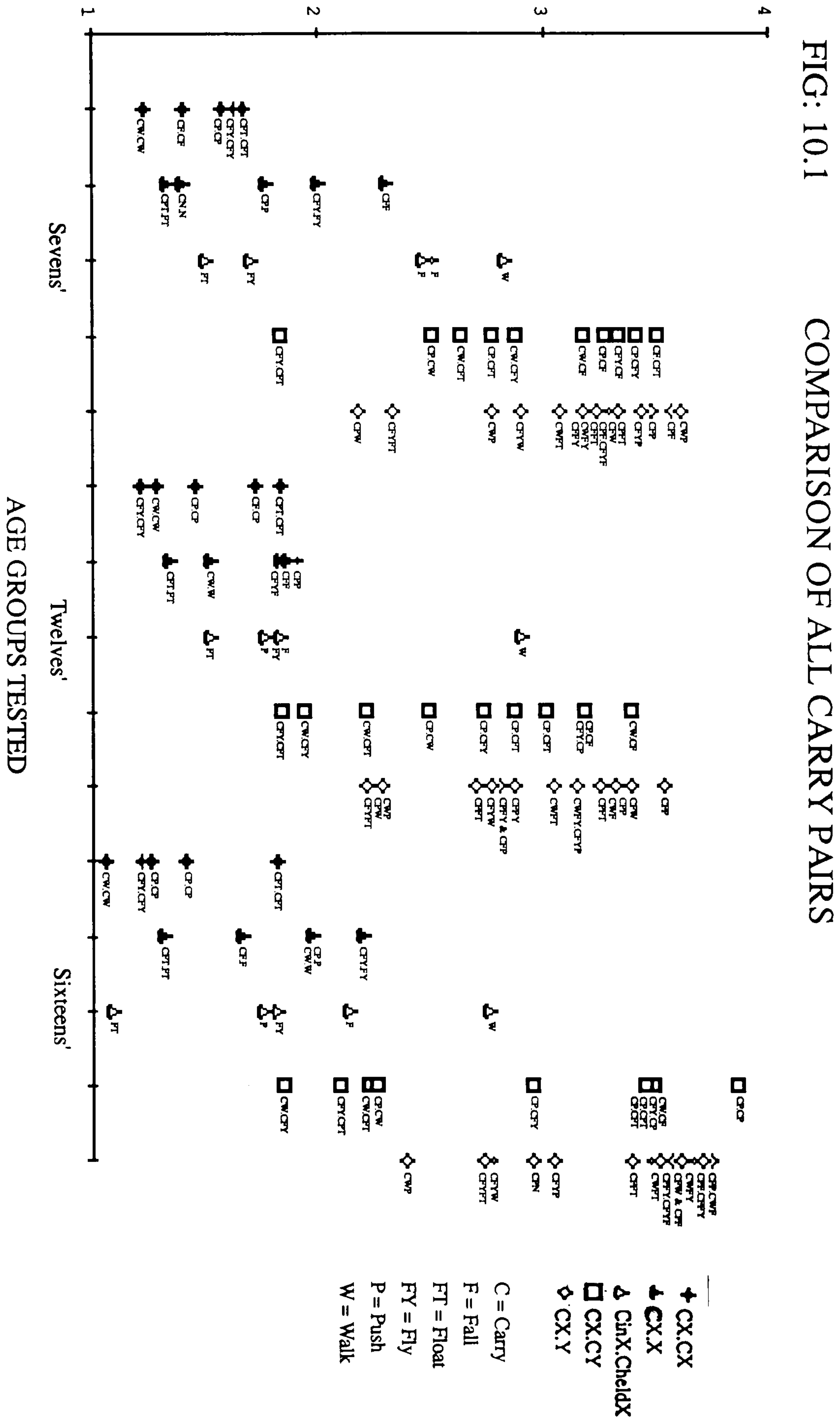


Table 10.2: Comparison of CARRY-IN and CARRY-HELD Motions

Example Name	Sevens' Mean	Twelves' Mean	Sixteens' Mean
CARRY WALK IN AND CARRY WALK HELD	2.83	2.90	2.75
CARRY FLY IN AND CARRY FLY HELD	1.70	1.83	1.81
CARRY FALL IN AND CARRY FALL HELD	2.47	1.86	2.13
CARRY PUSH IN AND CARRY PUSH HELD	2.50	1.76	1.75
CARRY FLOAT IN AND CARRY FLOAT HELD	1.50	1.52	1.09

It is important to try to ascertain the factors which contribute to the differences between CARRY-IN/HELD motions. These could be attributed to differences in attachment. In the examples actually used it is the CARRY-HELD motions that are animate in nature, and this may be another contributory factor to the observed differences, since Matching Task 2 suggests that a difference in the source of motion being animate is an important distinction used when assessing carry motions.

10.3.3 Comparison of CARRY X X motions

The suggestion that a carried object inherits the support and motion of the carrier predicts that a carried motion of a given kind should be seen as similar to the identical stereotypical motion. Therefore the subects were asked to compare the CARRY motion with its equivalent single stereotypical counter part. Table 10.4 summarises these results and shows that the values agree favourably with this prediction, it is not claimed however that a carry motion of a given kind is **identical** to the motion of that kind. Figure 10.1 illustrates that these scores tend to be a little higher than those of the comparison of CARRY-IN identities except for Float.

FLOAT again appears to fit outside the general pattern of results. The examples chosen for this comparison were a hot air balloon transporting passengers and an ordinary balloon suspended the air. These examples are perhaps too similar to each other and may have produced this unusually low result.

Table 10.3: Comparison of stereotypical motions with corresponding CARRY motions

Example Number	Example Name	Sevens' Mean	Twelves' Mean	Sixteens' Mean
8	CARRY PUSH AND PUSH	1.77	1.90	1.97
30	CARRY FALL AND FALL	2.30	1.86	1.66
32	CARRY WALK AND WALK	1.40	1.52	1.97
35	CARRY FLY AND FLY	2.00	1.83	2.19
40	CARRY FLOAT AND FLOAT	1.33	1.34	1.31

10.4 COMPARISON OF DIFFERENT CARRY MOTIONS

10.4.1 How similar are CARRY X CARRY Y pairs?

The CARRY X CARRY Y pairs are seen as having differences within pairs greater than those for CARRY-IN identities and the CARRY-IN/HELD comparisons. This is what is expected: the comparisons are between different motions. The results are shown in Figure 10.1 and in Table 10.4, e.g. the seven year old viewed the CARRY WALK and CARRY FLY motion as more different than the other ages.

Table 10.4: CARRY X CARRY Y pairs

Example Number	Example Name	Sevens' Mean	Twelves' Mean	Sixteens' Mean
5	CARRY FALL AND CARRY FLOAT	3.50	2.86	3.44
26	CARRY FLY AND CARRY FLOAT	1.83	1.83	2.09
9	CARRY WALK AND CARRY FLOAT	2.63	2.21	2.22
18	CARRY WALK AND CARRY FALL	3.17	3.38	3.47
22	CARRY FLY AND CARRY FALL	3.27	3.00	3.47
34	CARRY WALK AND CARRY FLY	2.87	1.93	1.84
36	CARRY PUSH AND CARRY FLY	3.40	2.72	2.94
6	CARRY PUSH AND CARRY FLOAT	2.77	2.72	3.44
12	CARRY PUSH AND CARRY FALL	3.33	3.17	3.84
14	CARRY PUSH AND CARRY WALK	2.50	2.48	2.25

10.4.2 How similar are CARRY X Y pairs?

The model suggests that these pairs should differ more than the CARRY X X motions. (See table 10.5).

Four comparisons (CARRY FLOAT FLY, CARRY FLOAT PUSH, CARRY FLOAT FALL AND CARRY FLOAT WALK) which should have been included were omitted by an oversight which was not detected until it was too late to remedy it.

Table 10.5: Carry X Y pairs

Example Number	Example Name	Sevens' Mean	Twelves' Mean	Sixteens' Mean
2	CARRY FLY AND WALK	2.90	2.79	2.75
3	CARRY FALL AND PUSH	3.47	3.52	3.72
7	CARRY FALL AND FLOAT	3.23	2.69	3.38
11	CARRY FALL AND WALK	3.30	3.38	3.63
16	CARRY PUSH AND WALK	2.17	2.24	2.94
17	CARRY WALK AND FLOAT	3.07	3.03	3.47
20	CARRY FLY AND FLOAT	2.33	2.21	2.72
21	CARRY PUSH AND FALL	3.57	3.38	3.63
23	CARRY PUSH AND FLY	3.23	2.76	3.50
24	CARRY WALK AND FLY	3.23	3.14	3.56
29	CARRY PUSH AND FLOAT	3.33	3.24	3.63
33	CARRY FALL AND FLY	3.17	2.86	3.66
37	CARRY WALK AND FALL	3.60	3.31	3.69
39	CARRY FLY AND PUSH	3.43	2.76	3.03
41	CARRY WALK AND PUSH	2.77	2.28	2.38
42	CARRY FLY AND FALL	3.23	3.14	3.59

Table 10.5 indicates there is agreement between the age groups with the following exceptions, CARRY FLY and PUSH, CARRY FALL and FLOAT, CARRY PUSH and WALK, CARRY PUSH and FLY, CARRY FALL and FLY and CARRY WALK and PUSH.

10.5 HOW SIMILAR ARE THE CARRY COMPARISONS TO THE EQUIVALENT STEREOTYPICAL SINGLE MOTION COMPARISONS?

10.5.1 Introduction

The model suggests that a CARRY motion can be seen as very similar to that of the motion of the CARRIER itself. If this is the case then the data collected from this test can be compared with equivalent results obtained from Matching Task 1 and there should be some correspondence between the two independently collected responses. This section assesses whether there are any differences between the judgements made by the separate age groups for different sets of pairs, discussing comparisons between data from Task 1 and Task 2 as follows:-

i. Comparison of CARRY X CARRY X with X X.
ii. Comparison of CARRY-In X CARRY-Held X X with X X.
iii. CARRY X X with X X.
iv. Comparison of CARRY X CARRY Y with X Y.
v. Comparison of CARRY X Y with X Y.

It should be noted that these comparisons are less reliable than those above, because they come from two tasks done with different children.

In order to examine the five sets of comparisons described above in more detail, the judgements for Matching Task 3 were plotted against the judgements from Matching Task 1.

1. Therefore, five graphs were plotted (Figures 10.2 - 10.6).

    1. CARRY X CARRY X with XX

    2. CARRY-IN X with CARRY-HELD X with XX

    3. CARRY X X with XX

FIG. 10.2: CARRY X CARRY X VERSUS X X.

7s',12s' and 16s' data.

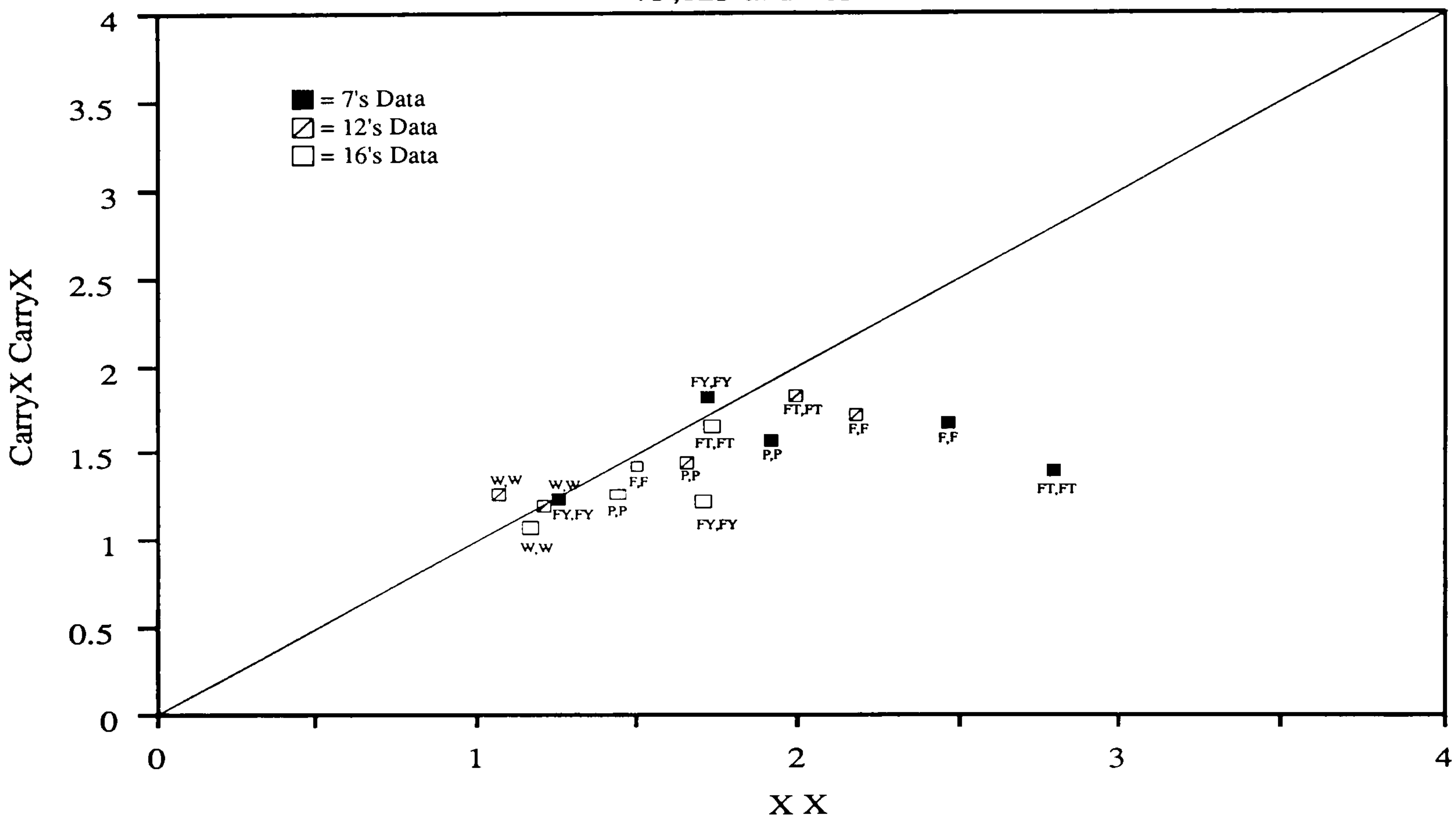


FIG. 10.3: CARRY X X VERSUS X X.

7s',12s' and 16s' data.

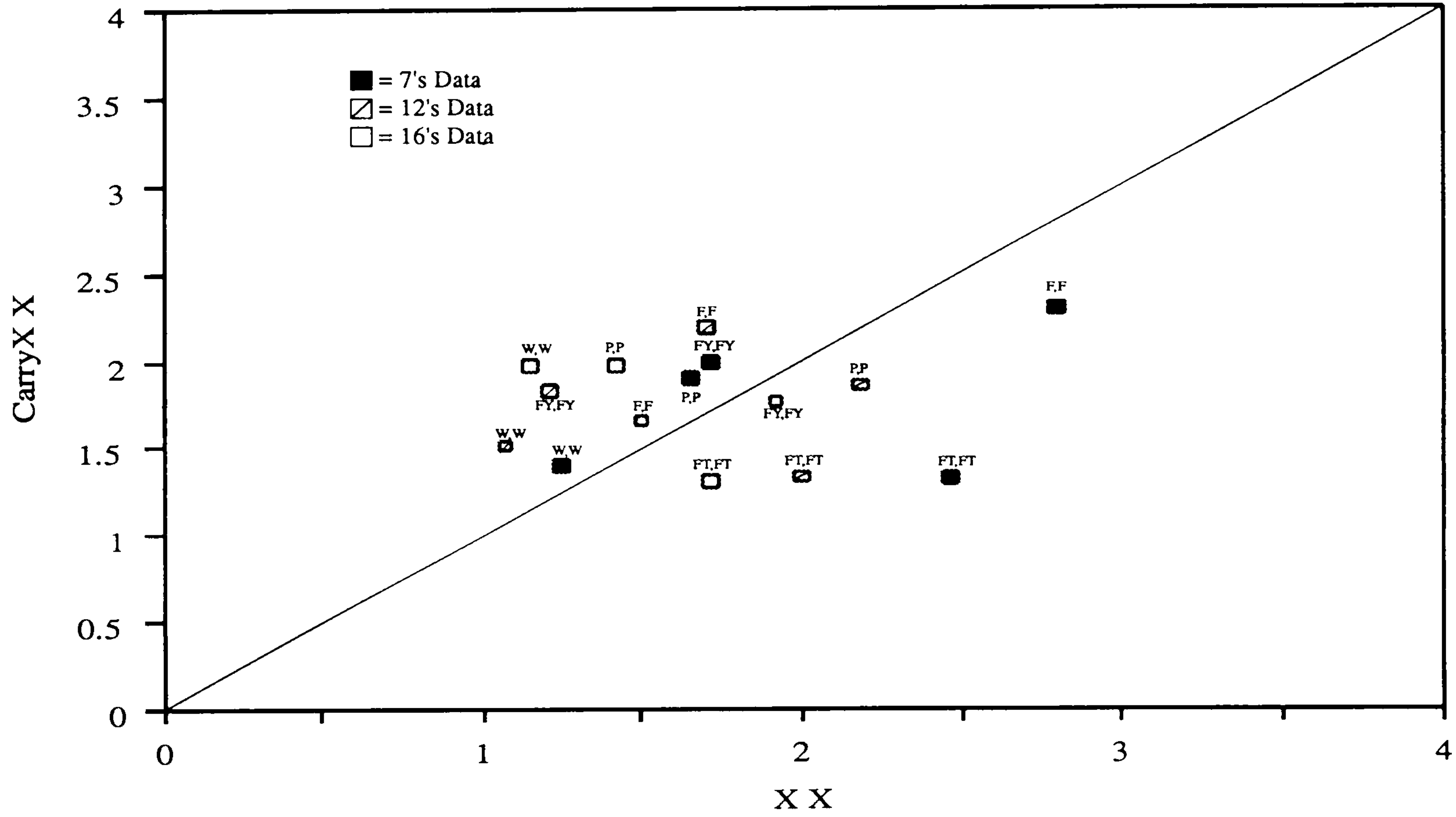


FIG. 10.4:CARRY-INX CARRY-HELDX VS.XX.

7s',12s' and 16s' data.

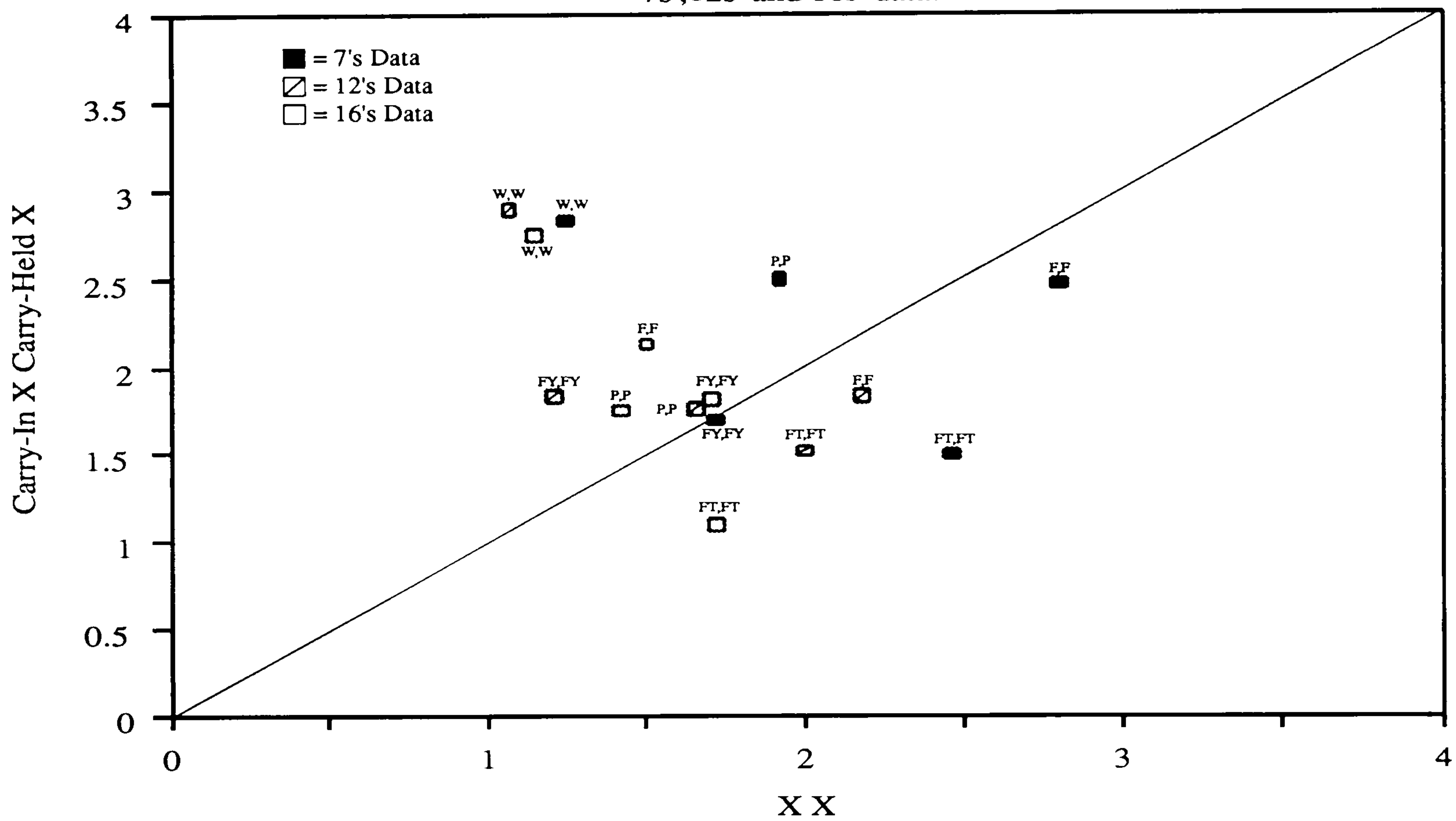


FIG. 10.5: CARRY X CARRY Y VERSUS X Y.

7s',12s' and 16s' data.

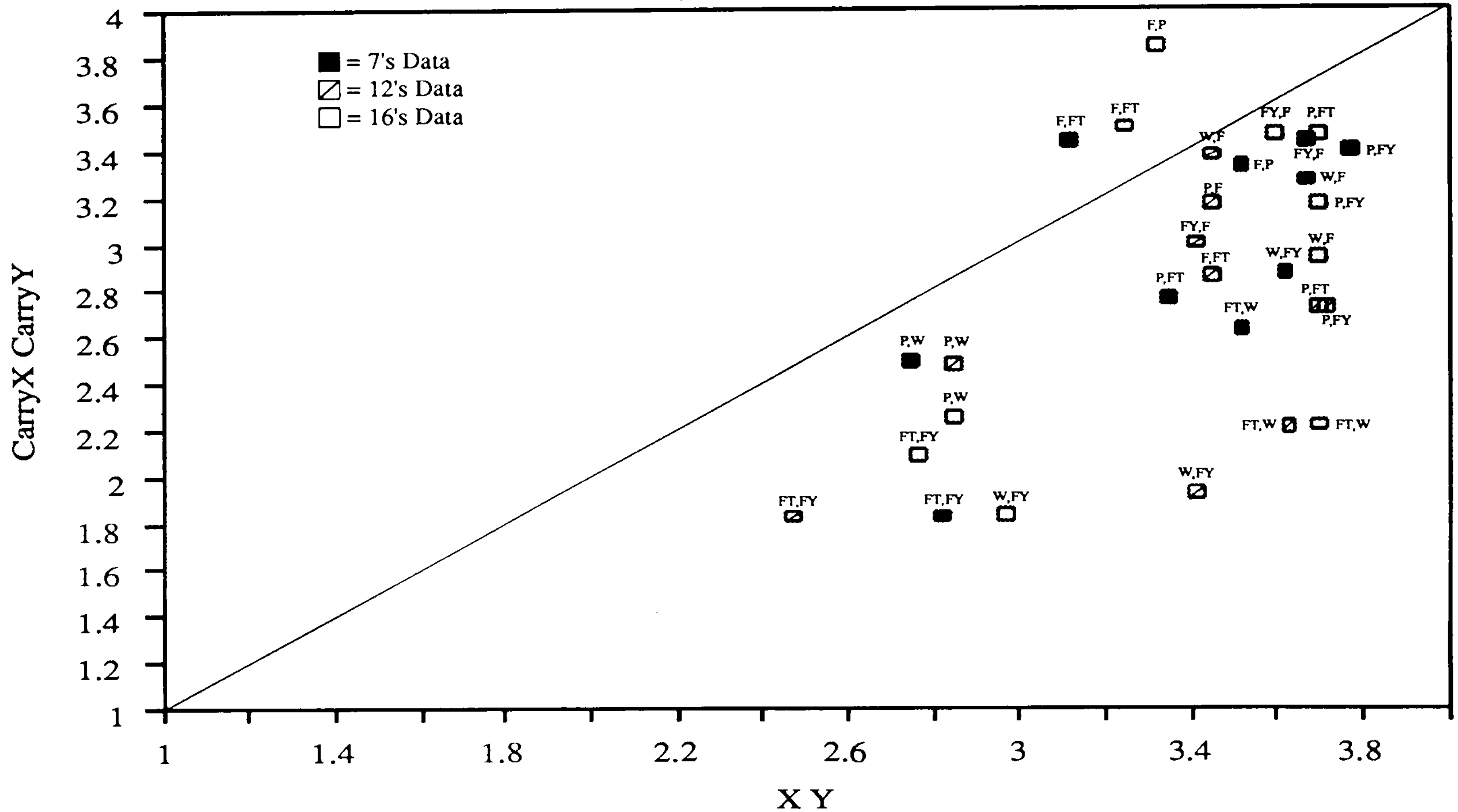
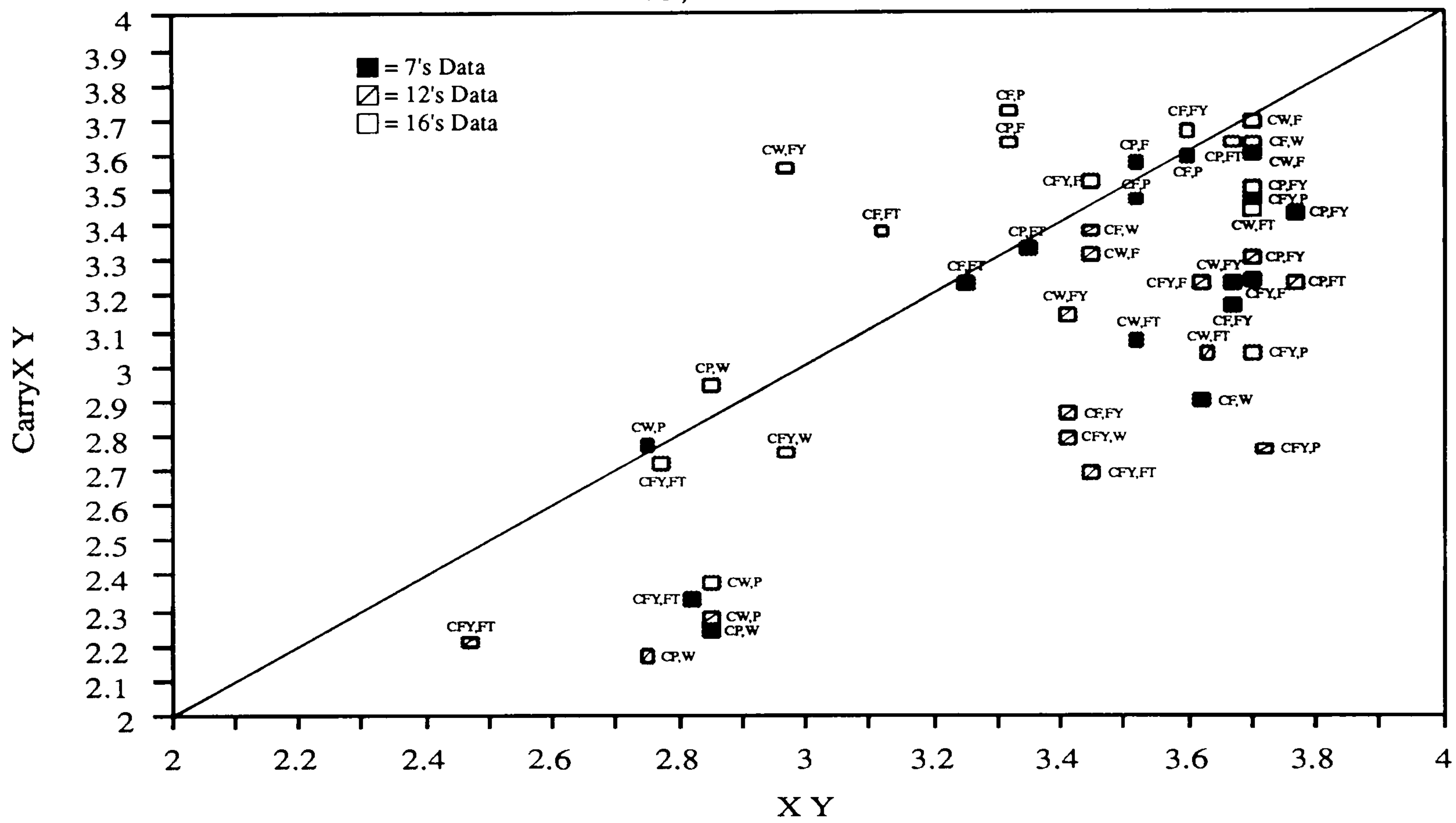


FIG. 10.6: CARRY X Y VERSUS X Y.

7s',12s' and 16s' data.



4. CARRY X CARRY Y with XY

5. CARRY XY with XY.

If the judgements are the same, the points will fall near a straight line slope of 1.

These graphs are discussed in sections 10.5.3 - 10.5.7.

10.5.2 Are CARRY X CARRY X pairs similar to X X pairs?

Figure 10.2 shows that the CARRY X CARRY X pairs are seen as similar to X X motions. However FLOAT and FALL comparisons are not seen as more different than the others by the seven year olds.

10.5.3 Are CARRY X X pairs similar to X X pairs?

Figure 10.3 shows that there is similarity between the CARRY X X pairs and the X X motions but not such good agreement as the CARRY X CARRY X and X X (See figure 10.3). All ages agreed FLOAT did not fit into the general pattern while the sixteen year olds did not find WALK and PUSH to be so similar.

10.5.4 Are CARRY-IN X CARRY-HELD X pairs similar to X X pairs?

Figure 10.4 shows that the motions of FLY, PUSH and FALL are seen as more similar than the WALK and FLOAT comparisons. Float continues to appear as problematic while differences in Walk comparisons could be explained by an animacy difference in the examples taken from Matching Task 1.

10.5.5 Are CARRY X CARRY Y pairs similar to X Y pairs?

The following comparison of data between matching task 1 and 3 provides another check upon the model's prediction that carry pairs are similar to the equivalent motion of the carrier. Carry X and Carry Y pairs are compared with X Y pairs.

Figure 10.5 illustrates the mean comparisons for all age groups tested and shows that the Fall comparisons exhibit the best fit i.e. are seen as most similar.

These are the FALL WALK
FALL FLOAT
FALL FLY

The PUSH comparisons show the next best fit.

These are PUSH FLY
PUSH FLOAT
PUSH WALK
and PUSH FALL.

However, FLOAT WALK
FLOAT FLY
WALK FLY
do not follow the general pattern. Only the CARRY FLY, CARRY FLOAT examples as identified in Section 10.6.2 as one which the subjects did not agree about and displayed a higher standard deviation/maximum standard deviation.

10.5.6 Are CARRY X Y pairs similar to X Y pairs?

The model predicts that a CARRY FLY is similar to a FLY motion and the above results suggested that this was a reasonable supposition. This notion can be tested further, if a CARRY X motion is compared with another stereotypical motion (which is not a CARRY - denoted by Y) to see if these pairs are are similar to the equivalent stereotypical motions. That is, CARRY X Y XY. Figure 10.6 illustrates the mean comparisons for all age groups tested.

It is interesting to note that most of the points fall on the lower side of the line in figure 10.6. XY pairs are seen as further apart than CARRIED CARRY X CARRY Y pairs. This is not unexpected in that the CARRY X CARRY Y pairs have at least CARRY in common.

10.5.7 Summary

In conclusion there is more agreement about ther similarity of identities than the discrepancies. The Float comparisons stand out as fitting outside the general pattern, another indication that the theoretical status of FLOAT requires review. These results however, indicate that the model's suggestion that a CARRY motion can be seen as very similar to the motion of the CARRIER itself is correct.

10.6 WHAT IS THE CONSISTENCY OF RESPONSE?

In order to determine whether the children from the three different ages responded to the questionnaire in a similar fashion the Wilcoxon signed ranks test was used, as previously described in sections 8.4 and 9.4.

When the mean value of each pair of comparisons was ranked by age as shown in table 10.7 then the T values for the 7/16 and 12/16 comparisons are within the 95% confidence limits, indicating there is not enough evidence to reject the hypothesis that any differences arose by chance. (For n = 41, 95% limits for T are 277 - 583).

10.6.1 Wilcoxon Test of difference between differently aged pupils

Table 10.6: Table of T values to show results of Wilcoxon Test to see if the different aged pupils identified the pairs similarly

n = 41

	Sevens	Twelves
Twelves	176*	
Sixteens	384	293

* Value outside 95% confidence limits

Next, as before not the judgements, but their **variability** is compared. For each comparison the standard deviation was divided by the maximum value it could have for the observed mean, and this value was ranked for each pair of comparisons by age as shown in Table 10.9. In each case the value of T falls at or outside the 1% significance level, supporting the view that there are real differences between the groups in the variability of their judgement.

Table 10.7: Table of T values to show the results of Wilcoxon Test to determine the differences in variability of responses of each age group

n = 41

	Sevens	Twelves
Twelves	125*	
Sixteens	93*	254

* Value outside 95% confidence limits

In order to identify problematic examples among the comparisons the mean values were plotted against the maximum standard deviation for each age group tested, as shown by Figures 10.7 - 10.10. This technique illustrates the pairs of motions which the pupils were unsure about i.e. when there was no consensus among each age group about the reply.

FIG. 10.7: MATCHING TASK 3. 7S' DATA.

Plot of mean versus s.d./s.d. maximum.

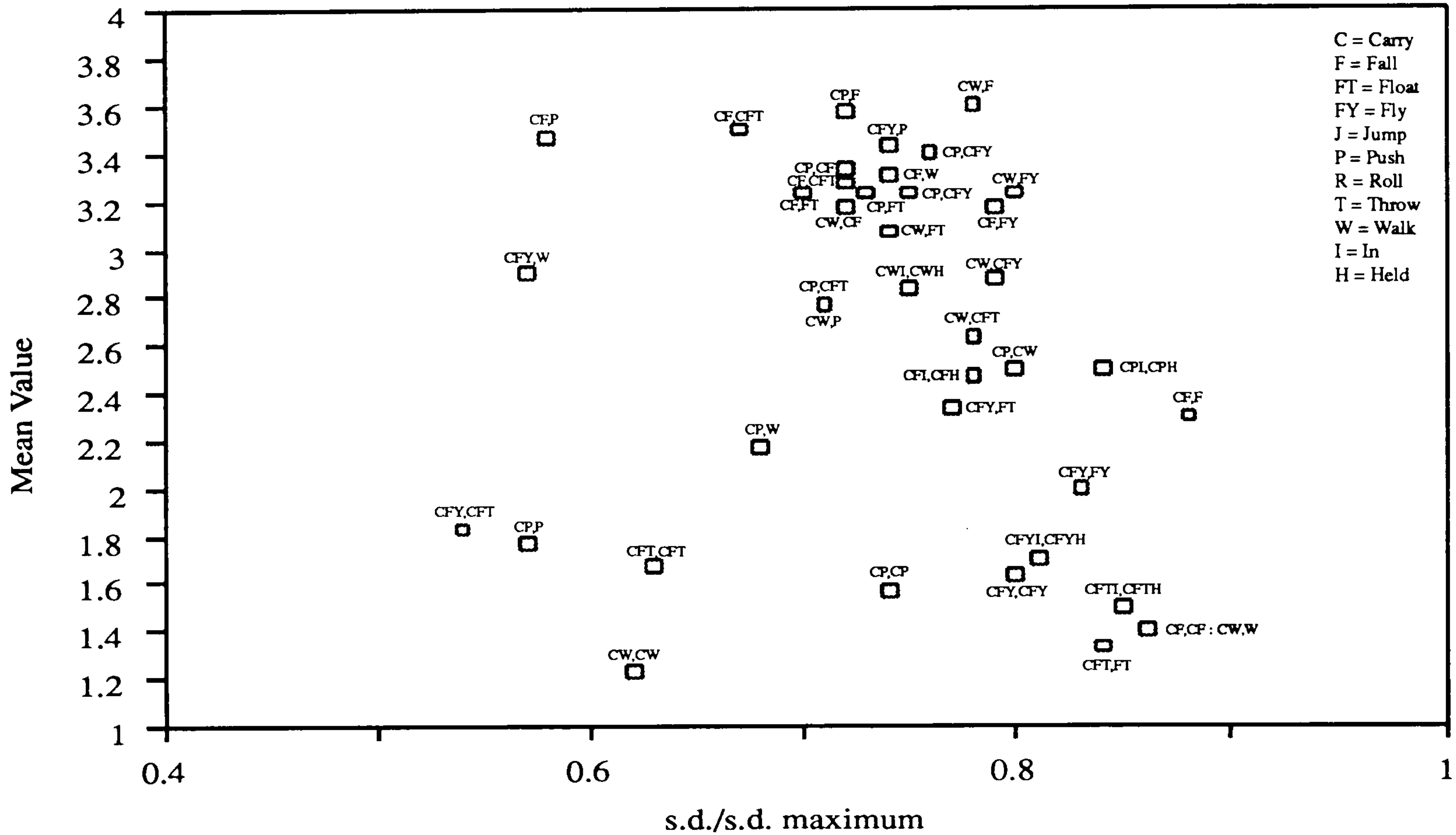


FIG. 10.8: MATCHING TASK 3. 12S' DATA.

Plot of mean versus s.d./s.d. maximum.

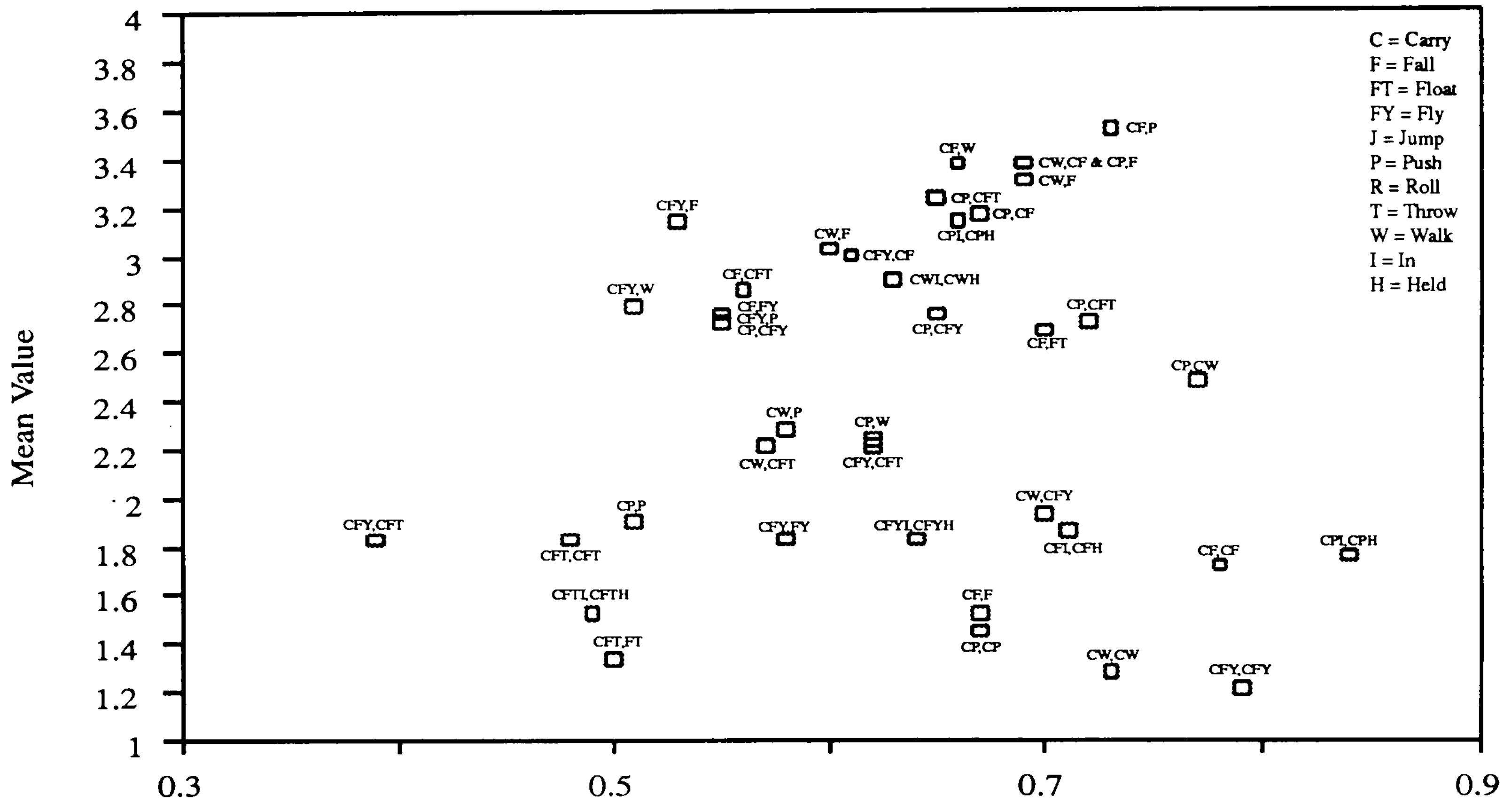


FIG. 10.9: MATCHING TASK 3. 16S' DATA.

Plot of mean versus s.d./s.d. maximum.

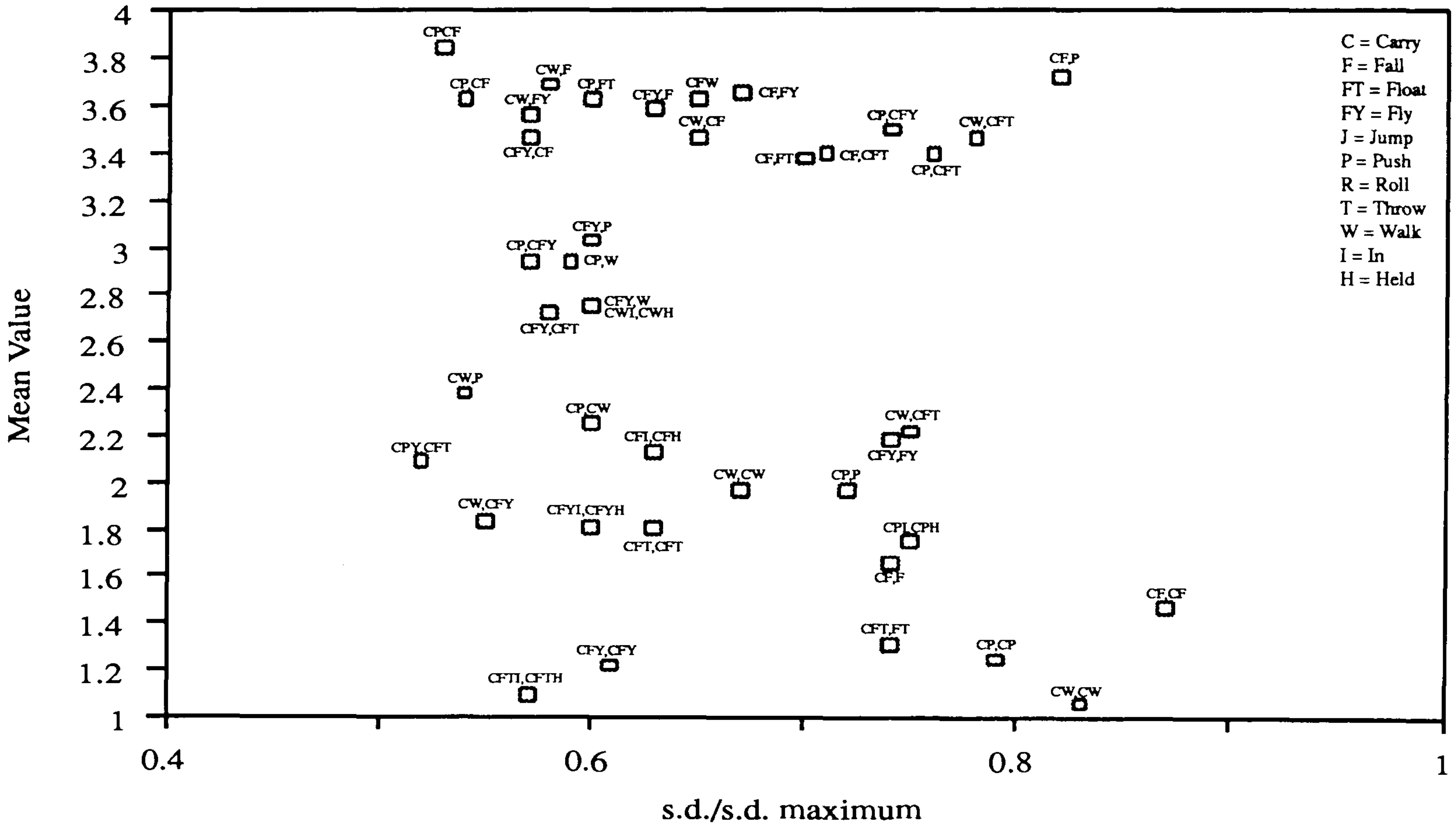
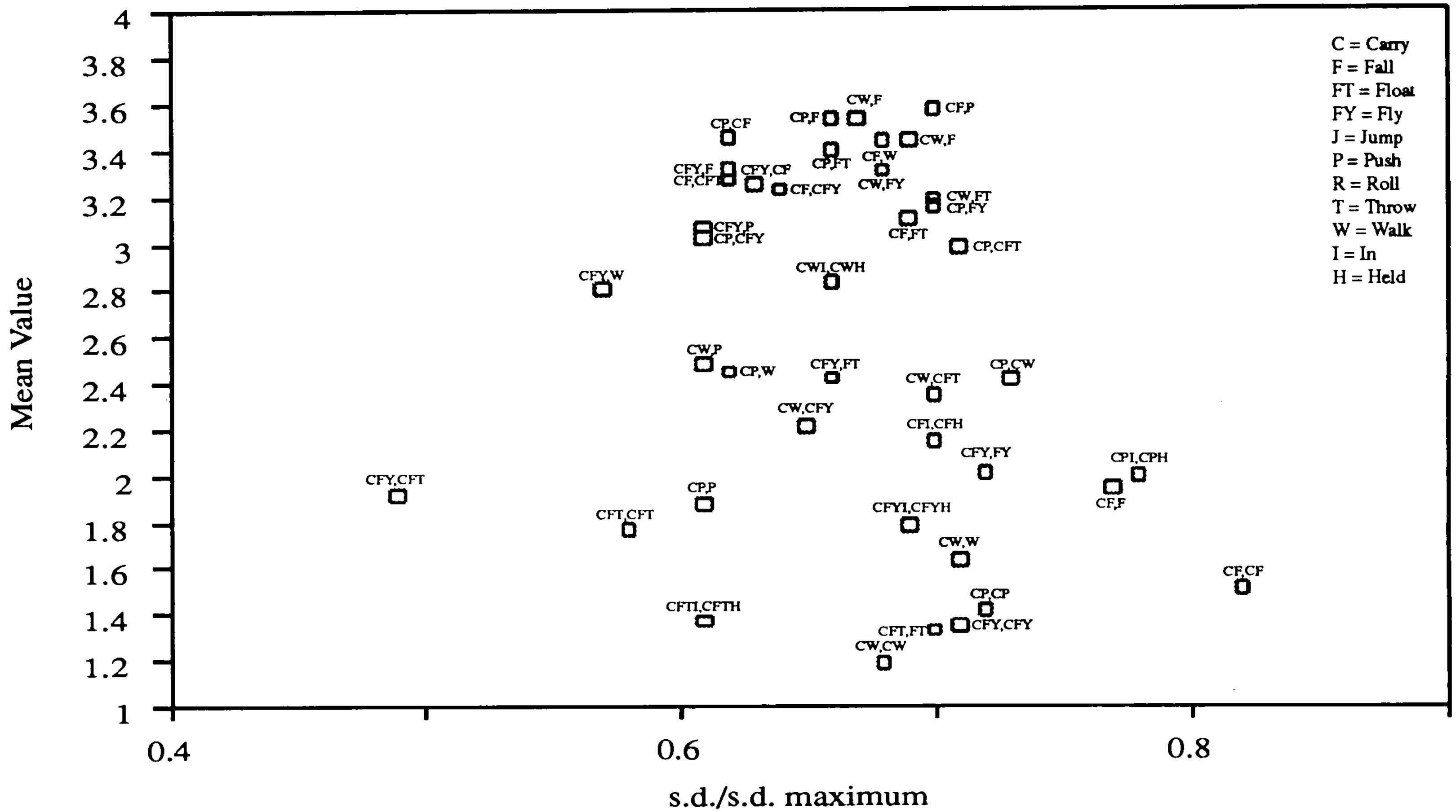


FIG. 10.10: MATCHING TASK 3. MEAN DATA.

Plot of mean versus s.d./s.d. maximum.



Further examination of these examples could suggest problems with the choice of particular pictures for comparison i.e. methodological anomalies in the construction of the task or point to areas where the model is unclear.

10.6.2 Discussion of examples about which the subjects agreed and disagreed

It is interesting to note that the examples which the different age groups all agreed most strongly about were:-
(Standard deviation/standard deviation maximum of 0.58 and below).

CARRY FLY, WALK and
CARRY FLY, CARRY FLOAT.

The examples which the different age groups all differed most strongly about were:-

(Standard deviation/standard deviation maximum of 0.8 and above).

CARRY PUSH-IN and CARRY PUSH-HELD
CARRY FALL and CARRY FALL.

Float proved to be a problematic comparison throughout the Matching Task 3 which suggests the role of FLOAT needs further theoretical clarification as discussed in chapter 11. Again there is no systematic pattern from this set of data which can point towards places where the theroetical account is incorrect.

10.7 CONCLUSION

The results of this questionnaire are discussed in three sections. The first part answers questions about the accuracy of the model's predictions about the role of CARRY in a commonsense understanding of causes of motion. The second part discusses the findings in relation to the different age groups tested, while the third part makes some suggestions about which areas of the model require further clarification.

10.7.1 Do people group CARRY motions as predicted by the model?

The results suggest,as the model predicts, that the movement of a CARRIED object is perceived as part of the motion of the CARRIER. The most striking evidence for this statement is the similarity of the CARRY X X comparisons for all ages tested. The results also suggest that subjects found the movement of a carried object which is flown, pushed or floated etc. as similar to the corresponding simple motion of flying, pushing and floating etc. (the CARRY X X comparisons). It is therefore reasonable to suggest that when the motion of a carried object is scrutinized its source of effort and support is also considered i.e. the motion of the CARRIER. A second form of analysis revealed that the model's prediction could be supported by further comparisons. The CARRY X CARRY Y and CARRY XY judgements were compared with those of the XY pairs from Matching Task 1 and although these results need to be treated with more caution as they are taken from two separate tasks examining different children, similar responses were found.

However, objects which inherit their support and effort from other objects are not necessarily considered alike as regards to motion. The model predicted that there are three further distinctions within the CARRY paradigm. These are objects which are fixed to a carrier which should be seen as different from objects which form part of a carrier or CARRIED IN or ON the carrier.

It was not possible to test for the PART-OF distinction in this Matching Task as previously discussed in section 7.3.6 but the results show that subjects perceived a difference between the movement of objects which are CARRIED-IN or CARRIED-HELD by the carrier. This result suggests that the type of attachment or support between pieces of a scene could well prove to be an important consideration in the perception of objects.

10.7.2 Are the results similar for the three age groups tested?

When the Wilcoxon signed ranks test was used to obtain more information about the way the different age groups judged the paris of motion for the whole test there was no significant difference. There were significant differences in variability of response between the ages but no systematic pattern in differences in response per age could be identified which could given any new information on the state of the model itself.

10.7.3 Points for further clarification

Only one set of CARRY HELD comparisons were used throughout the task and so a more systematic testing of CARRY HELD differences would be desirable. An interesting point is that the examples which were used in this task to distinguish between CARRY IN/HELD motions also exhibited an animacy difference. Therefore more inanimate examples such as cranes and robots holding other objects need to be tested to see the true value of the CARRY distinction since the results of Matching Task 2 (see chapter 9) demonstrate that animacy is an important feature when cause of motion are considered.

The CARRY-PART-OF distinction was not tested and merits further research. A different sort of task may well need to be designed to investigate this notion further and it would be interesting to probe in greater detail how people do recognise different objects in a scene. It remains in the next chapter to draw together the results of the three tasks.

11. SUMMARY AND INTERPRETATION OF RESULTS

This chapter discusses the overall results of the major test of the theoretical model i.e. Matching Task 1 with respect to the other subsidary tests. Section 11.1 **A First test of the commonsense model of motion** uses the data from the subsidary tasks to help to explain some of the results which did not fit the theoretical predictions. 11.2 **Possible causes of mismatch between theoretical predictions and empirical data obtained from the younger children**, proposes three reasons for this discrepancy. The final section 11.3 **What remains a puzzle?** identifies some remaining problems and suggests further ways to test the model.

11.1 A FIRST TEST OF THE COMMONSENSE MODEL OF MOTION

11.1.1 The role of animacy in a commonsense understanding of motion

The rank correlations between theoretical predictions and empirical scores improved for all ages with the addition of an animacy allowance. The empirical evidence suggests that the movements of live objects are thought about differently than are the movements of things which are not alive. We can draw some ideas from Piaget's study of animism about how children think about the movement of living things.

Piaget (1928) defines animism as the child's tendency to endow physical objects and events with the attributes of biological and psychological entities, that is with attributes of life and consciousness. Piaget suggests four stages in its development. He was however cautious about overstating his findings, saying that the results only indicate a general direction of thought not a comprehensive and coherent system of beliefs. These stages are as follows:

1. Almost any object is potentially conscious,given the right conditions. E.g. A stone is not conscious but will 'feel' when it is moved.

2. Potentiality for consciousness is generally attributed to objects which regularly **possess some kind of movement**, that is those whose special function is movement.

Thus, a bicycle and the wind may know or feel, but a stone cannot.

3. Only objects capable of spontaneous motion are conscious: the sun and wind can be but no longer objects such as a bicycle.

4. Consciousness is only attributed to people and animals.

Piaget placed his work on animism within a causal framework and suggested that both animism and artificialism are the fruits of precausality. He defined precausality as the child's lack of differentiation between physical causality and psychological or logical motivation. He says:

"Childish causality is therefore not visual, in other words is not interested in spatial contacts nor in mechanical causation. It is intellectual, that is to say, full of considerations that are foreign to pure observation: justification of all phenomena, syncretistic tendency to connect everything with everything else, in short, confusion of physical causality with psychological or logical motivation. Hence once again, precausality".

Piaget's evidence has been taken to show that activity and movement do become the basis for children's decisions about what is alive. Carey (1985) however, maintains that childhood animism is not, as Piaget suggests it is, a lack of a schema for mechanical causation. She argues that mechanical causation is present in preschool children (see Bullock, Gelman and Baillargeon 1982) and Schultz (1982) whose studies show that phenomena involving propagation of physical forces through space, whether involving contact or not are interpreted mechanistically.) Carey suggests that the child's animistic attribution of "alive" to inanimate objects reflects the child's struggle in distinguishing animals from non animals more than distinguishing living things (plants) from non living things. Although her data suggests that for no child does movement or activity (autonomous or otherwise) constitute the single criterion for life, it does remain a feature of the child's reasoning.

Therefore when considering how the model can be improved animism will be an important consideration and the development of these ideas deserves further attention (see 12.7).

11.1.2 A clarification of the role of CARRY in a commonsense understanding of motion

It appears that the model's suggestion that a carried object will be seen as part of the carrier's motion is basically correct and also depends upon the carried objects type of attachment to the carrier. It was therefore in retrospect unwise to have chosen two different types of CARRY motion (i.e. CARRY-IN and CARRY-HELD) for Matching Task 1. It was also perhaps unwise to have tested CARRY in the same way as the other stereotypical motions. This appears to be a possible explanation of why CARRY comparisons, though often generally fitting the theoretical predictions , provided several anomalies. One of the model's assumptions is that an object is recognised as a whole unit if all its pieces move together, this assumption being also recognised by Piaget (1980) as an important relation at the root of the first operational ideas of movement and speed. He says that the motions of movement and speed "are logical operation forming systems which are reversible and capable of synthesis. These operations are established before the occurrence of mathematical groups and are a precondition for subsequent mathematization".

A clinical interview technique developed around Ogborn's prolog version of the model of commonsense causes of motion which explicitly shows carried objects inheriting properties from the carrier might provide a useful tool to explore in more detail how people's ideas about objects are recognised and differentiated.

11.1.3 What other anomalies remain unexplained?

Even after an animacy allowance was added to the results of Matching Task 1 some anomalies remained between the theoretical predictions and the empirical data. These are:-

i. The theoretical description of FLOAT.

ii. Problems with certain THROW and JUMP comparisons.

It appears that there is a real problem with the theoretical description of floating objects.

After talking to pupils of different ages it appears that floating is a difficult notion for them to explain. I suspect that two analogies are used to explain floating objects. Objects which float in air can be divided into two different groups. One group contains objects which float and remain in the air e.g. clouds, and birds gliding while the other group consists of objects which are light and float in the air for only a limited period. This latter group of objects inevitably have to fall down to the ground, albeit more slowly than other objects. It does not appear unreasonable to suggest that our early experiences of floating and learning about the behaviour of light and heavy objects arises from experimenting with falling objects. This suggests that children should see floating objects such as balloons and feathers as similar to falling objects.

However, a different mode of explanation is needed for objects in the first group because these objects do not have to come down to the ground in the same way as the others. I believe that another model may be recruited to explain the floating of such objects. The closest analogy from experience may be that of a CARRY type motion. The clouds could be seen to be carried along by the air; that is the clouds have to be supported and moved by something, and that agent of motion and support can be seen as the air.

The problems associated with the THROW JUMP and PUSH JUMP comparisons seem to be methodological rather than theoretical. The choice of examples for JUMP illustrated motions in two different directions. The one of the horse in the downward direction could be interpreted as being more like a FALL than a JUMP and in fact upon closer inspection of the empirical data, the empirical value for the PUSH JUMP difference was close to the theoretical prediction for a PUSH FALL comparison.

The unexpectedly small difference found between ROLL and THROW has been discussed in Chapters 8 and 9, and suggests that the cause or type of EFFORT being similar might take precedence over the rest of the object's motion when assessing differences. The request in this questionnaire to focus on the reasons why two objects move, may have reinforced such a tendency or induced it.

11.2 POSSIBLE CAUSES OF MISMATCH BETWEEN THEORETICAL PREDICTIONS AND EMPIRICAL DATA OBTAINED FROM THE YOUNGER CHILDREN

The goal of developmental cognitive psychology is to document the nature of emerging thought and knowledge and to explain why children seem to know some things and to think like adults in some ways but not in others. Using some ideas from Piaget, and from the work of other neo-Piagetians, three reasons can be proposed to explain why the seven year old data shows more variability than that of the other ages. These are:-

i. Limitation of processing capacity.

ii. Egocentricity.

iii. Concentrating on particular features in the Matching Task and not generalising.

i. Limitation of processing capacity

Several developmental theorists have proposed limits on children's information - processing systems (e.g. Case, Kurland and Goldberg (1982), Pascual Leone (1970). They argue that developmental growth reflects changes in "capacity" or processing space. According to one account Case (1972), processing capacity is not necessarily dependent on maturation per se but increases with the acquisition of specific experience at various mental tasks. Piaget however explains the child's inconsistency of response with his/her inability to give complete logical justifications or reasons for what he/she is doing. Piaget proposes that the child needs to become simultaneously conscious of two or more elements when reasoning. Case agrees with Piaget but insists that the reason why the child cannot reason with two elements simultaneously is due to an overload in the memory system. Regardless of whether memory capacity increases owing to general developmental growth or to practice in specific cognitive tasks or both, limits on capacity seem a likely source of the child's partial, limited competence.

ii. Egocentricity

It can be proposed that the seven year olds are more vulnerable to errors and fallacies when reasoning than the older ones. These sources of error can be due to the egocentricity of the young child. For Piaget egocentrism can be roughly defined as a failure to differentiate and distinguish clearly between one's own point of view and another's. Piagetian egocentrism is assumed to be very prevalent in early childhood and to decline thereafter.

Piaget states:-

"The whole perspective of childhood is falsified by the fact that the child being ignorant of his own ego, takes his own point of view as absolute, and fails to establish between himself and the external world of things that reciprocity which alone would ensure objectivity".

A relevant example of egocentrism from Piaget is his identification of different uses of the term 'because' in children's spontaneous talk and reactions to a number of set tasks. These are:

1. **Causal** explanations which establish a cause and effect relationship between two facts, (e.g. He tripped because the pavement was uneven).

2. **Psychological** explanations which establish a cause and effect relation between an intention and an act, (e.g. I hit him because he took my toy).

3. **Logical implication** which establishes a reason - and - consequence relation between two ideas or two judgements, (e.g. I know that animal is not dead because it is still moving).

Piaget found that the preoperational child (2 - 7 years) does not discriminate between these three kinds of relations. In fact his response is more like an "and" or "in such a manner that" rather than "because". However even a consecutive relation is not employed consistently. The child uses a mixture of explanations indisciminately, since it is suggested that the child at this stage is not concerned about the kind of relationship in question but his thinking consists of a mere **juxtaposition** of facts or ideas.

This analysis suggests how it may have arisen that when asked to consider "reasons why things move", younger children may have varied much more than older ones in what they paid attention to.

iii. Concentrating on particular features in the Matching Task and not generalising

All the Matching Tasks were designed to probe the nature of children's generalisations about motion and if young children find it difficult to generalise then this fact could account for why they perform more variably on the Matching Tasks.

Piaget (1928) says that the child always forms his judgments from an immediate and egocentric point of view which makes him incapable of grasping the relativity of ideas to the extent of being able to generalise them. He also emphasises that thoughts and processes which are implicit and not available to consciousness cannot be subjected to testing and logic. He argues that as long as meaning is only implicit it remains subject to all the fluctuations of subconscious thought. Piaget proposes that children in their spontaneous reasoning infer only from the particular to the particular. All the data collected are 'mental experiments' carried out on an individual case without any attempt at generalisation or appeal to laws previously generalised. Childish reasoning does not move from universal to particular or particular to universal but from part to part.

An example from some interviews with the seven year olds illustrates this type of reasoning. When they were asked to compare the motion of a cart and a horse, they said the motion of these two objects were different because the wheels make a cart move and the legs make a horse move.

Piaget suggests that immediate perception is the measure of all things: that the child sees things in terms of the momentary perception which is taken as absolute and therefore makes no attempt to find the intrinsic relations existing between things. Therefore the internal relations of objects are not considered and so things are either conglomerated into a confused whole (syncretism) or else considered one by one in a fragmentary manner devoid of synthesis.

My own view is that iii. is the most important reason for the seven year olds variability of response, while recognising that for Piaget ii. and iii. are all aspects of the same thing. This difference also illustrates the difficulty in trying to devise a task suitable for a large age range of children and although attempts were made to minimise the verbal content it would not be advisable to use this type of methodology with children below seven years of age.

11.3 WHAT REMAINS A PUZZLE?

The discrepancies which remain such as the theoretical classification of FLOAT raise such questions as:-

1. Are the present terms of the theory correct?

2. Is CONTROL too broad a term not providing sufficient distinction between the stereotypical motions?

3. How do ideas about the stereotypical motions develop?

4. Does the understanding of certain types of motion precede others?

5. How do notions of animacy develop?

These ideas are given further consideration in Chapter 12 which discusses how the model might be improved.

12. CAN THE COMMONSENSE MODEL OF MOTION BE IMPROVED?

This chapter suggests ways in which the commonsense model of motion might be improved. The **Introduction** questions some of the previous model's basic assumptions while the second section **What are the components needed to construct a set of stereotypical motions?**, proposes that the three primitive actions of SEE/HOLD, LET-GO and SELF MOVEMENT could provide a basic understanding of movement. The third section, **Predicting the differences between the stereotypical motions** proposes a new set of theoretical differences which are tested against the empirical data the results of which reported in section four, **Synopsis of Results obtained from comparison of new theoretical predictions with empirical data.** Section five **The comparison of correlations from the previous and reformulated theoretical models** shows there is an improvement in the new correlations which is most marked with the addition of an animacy factor. Section 6, **Multi-dimensional scaling** introduces a further statistical analysis of the new model while section seven **A possible development of animacy** suggests that a more fundamental account of animacy should include some developmental hypothesis. The final section **Future Research** proposes the use of Frames as a possible representation for a developmental model of motion.

12.1 INTRODUCTION

A first attempt at trying to improve the model (not in such a fundamental way as proposed in chapter 13) is to question some of its basic assumptions.

1. Is it reasonable to think that all the stereotypical motions are at the same basic level? Are there some which are more basic than others? For example ideas about flying probably emerge from something like a WALK type motion. In that case FLYING could be thought of as rather like WALKING in the air. In turn, it is probably the child's realisation of its own movement that helps him/her to arrive at a category of autonomous motion such as WALK.

2. How do these causal ideas about motion arise? If thinking is causal, following Piaget, then the basic ways of thinking are constructed through ACTION very early in life. Action and movement lead to the construction of the notions of object, time, space and cause.

3. Is it reasonable to assume that motions are partly identified by their closeness to the earliest actions performed in childhood?

Therefore one way to reformulate the model would be to provide a broad picture of the construction of classes of MOTIONS from ACTIONS. This chapter therefore explores the possibility of constructing the stereotypical motions from a set of primitive actions and incorporating them into a reformulation of a commonsense model of motion, to be tested against the available data.

12.2 WHAT ARE THE COMPONENTS NEEDED TO CONSTRUCT A SET OF STEREOTYPICAL MOTIONS?

12.2.1 What are the primitive components of a commonsense theory of motion required to do?

The commonsense model of motion to date has assumed that the world is composed of a variety of objects which occupy a topological space. Under normal circumstances many of these objects never move and may create obstacles to the movement of other objects. However if their means of support fail then they do move in quite a spectacular way - they FALL down.

The causal model also proposed that people do not consider motion to be a permanent state of affairs for different objects; things start and then they stop moving. Objects do not start moving in the same way and the starting process is connected to how people perceive the particular cause of motion. Some objects need an external agent to start their movement; while others are able to take "charge-of" and cause their own motion. The latter type of objects tend to be animate in nature and the empirical evidence suggests that they exhibit the special property of **control** during the course of their movement. This property provides a sharp differentiation from other types of motion.

The commonsense model of motion can be improved by identifying the primitive actions in which the child is engaged in order to understand a world of objects occuping a topological space. These actions should permit a causal mechanism for reasoning about motion and should give rise to levels of stereotypes, starting with primitive stereotypes from which the others can be constructed. If the model can propose a limited number of prototypical actions from which the nine classes of motion are generated, then differences such as animacy and control may also follow naturally and there will not be any need to patch these factors into the previous version of the model.

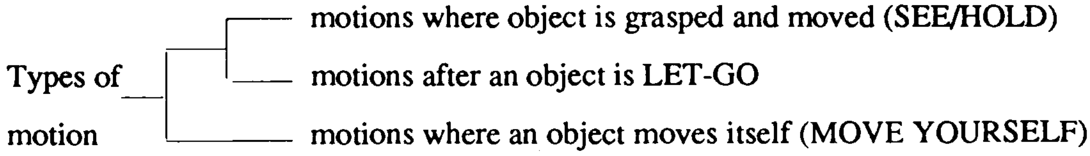
The construction of the stereotypical motions from the primitives might substantiate the model's assumption that objects are differentiated by their potential movement and that parts of an object can be distinguished from whole objects when their support and motion become differentiated ie a CARRY motion is translated into another type of motion.

12.2.2 What sorts of actions appear to be the most likely candidates to form primitives from which other motions might develop?

A Piagetian account of the beginning of conceptualisation of motion might run as follows. The child has an innate grasping reflex, and an innate ability to attend to movements in the visual field. From grasping, arise actions of taking hold of objects, displacing them, and letting them go. From noticing movements arises in the end the notion of an object. The coordination of these two starting points (in what Piaget calls near and far space respectively) can lead to a first conceptualisation of causes of motion. The term SEE/HOLD used below reflects this need for coodination of hand and eye. The child's own ability to move itself adds the element of autonomous motion. So a triplet of basic types of motion might be SEE/HOLD, LET GO and SELF MOVEMENT.

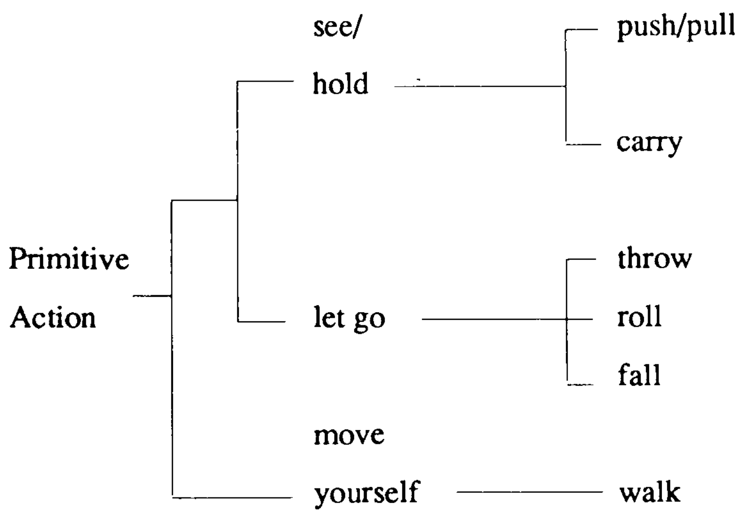
Figure 12.1 proposes how different types of motion can arise from these three basic actions.

Figure 12.1: Motions derived from three basic actions



The network of figure 12.2 suggests how further motion stereotypes might develop by differentiation within these three.

Figure 12.2: Development of stereotypes from three basic actions



12.3 PREDICTING THE DIFFERENCES BETWEEN THE STEREOTYPICAL MOTIONS

12.3.1 Defining the differences between the classes of motion

A reformulation of the model could then take account of the three primitive actions proposed above of See/Hold, Let-go and Self Movement. If the subsequent motions are compared with each other in terms of these primitive actions see Figure 12.3 then some basic constructions about objects and causes can be postualted.

Figure 12.3: The role of primitive action in understanding the movement of objects, action as a cause, and self as a cause

WORLD OF OBJECTS	Objects which move themselves i.e. PEOPLE. SELF seen as CAUSE and OBJECT through action of SELF MOVEMENT.	Produce	WALK FLY JUMP motions
	Things which are manipulated through the action of LET-GO lead to the recognition of object movement.	Produce	ROLL THROW FALL motions
	OBJECTS and AGENTS causally paired and physically joined. Action of SEE/HOLD produces a cause.	Produce	CARRY PUSH motions
	Fixed objects.	Produce	State of non motion i.e. STILL or at REST.

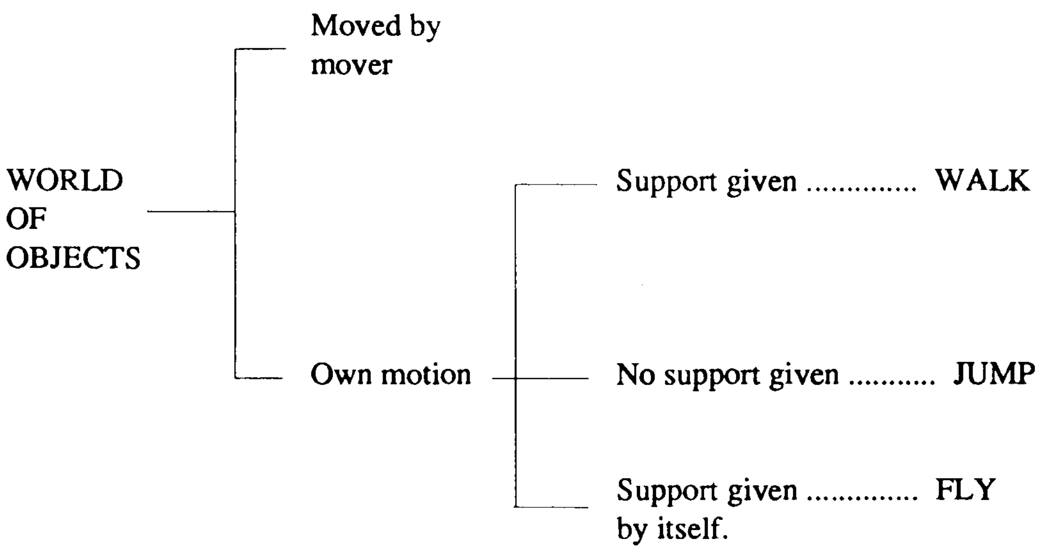
12.3.2 Development of FLY and JUMP

If a stereotypical motion of JUMP exists, it could develop in two ways. One would be to see it as 'moving oneself' (WALK) but up in the air. This means it would be close to FLY. Another way would be to see it as analogous to THROW, but involving the idea of 'throwing' yourself in the air. Both suggestions rely on analogical relations.

FLYING is a motion which cannot be directly experienced by the child and is a "projected" understanding. The commonsense model of motion is now proposing that ideas about FLYING and FLOATING are rationalised rather than constructed through direct action. Flying can be alternatively described as an action where the moving object e.g. the bird or aeroplane holds itself up and is also able to move itself. Therefore the source of motion and support are identical. The only other type of motion where this is the case is CARRY and so FLYING may also be thought of as CARRYING yourself in the air.

Figure 12.4 below describes WALK, JUMP and FLY as classes of autonomous motion.

Figure 12.4: Network to describe how WALK, FLY and JUMP belong to a group of autonomous motions



12.3.3 Two derivations of FLOAT

Section 11.1.3 suggested that ideas about the motion of FLOATING objects, can be seen as similar to FALLING or CARRIED objects. This means FLOAT can be derived from two primitive actions, LET GO and SEE/HOLD. The primitive action of LET-GO or alternatively from SEE/HOLD. If FLOATING is thought of in terms of a motion similar to a LET-GO action then it would include such objects as a feather and a balloon. While if FLOATING is thought to be derived from a SEE/HOLD action then objects such as clouds would be thought to move in this way. Therefore the revised model proposes two possible derivations for a FLOAT-type motion.

12.3.4 What other features of difference distinguish between each stereotypical motion, apart from primitive actions?

The notions of **support** and **effort** need to be included as important features of discrimination between stereotypical motions, while the notion of **control** requires further clarification. The notion of control is probably connected to or derived from an understanding of causality, which is in turn probably constructed during the sensori-motor period. An appreciation of the notion of control is also connected to the source of effort since an object which can provide its own effort can also change the course of its own motion.

The younger children also discriminated sharply between moving objects which were alive. However this feature is not easily translated into a table of differences and has been omitted from Table 12.1 below, since it is possible to have both types of objects i.e. animate and inanimate participating in all the stereotypical motions except for FLOAT (B) and JUMP.

The previous version of the model also predicted that Falling is very different from other motions because it does not require any effort. The notion of Effort needs to be distinguished not only more clearly in terms of its presence or absence but also in terms of the nature of its source. All these extra features of difference are incorporated in Table 12.1 below. The features to do with Control and Effort have been further refined by adding a feature of agency.

Table 12.1: Assessment of differences between the classes of motion using five features of difference

	FEATURES OF DIFFERENCE				
CLASS	AGENCY	CONTROL	EFFORT	SUPPORT	ORIGINAL STEREO-TYPE
WALK/ RUN	Itself	Controlled	+Effort	Ground	Self Movement
FALL	No-prev-ention	Free	-Effort	None	Let go
FLY	Itself	Controlled	+Effort	Itself	Self Movement
ROLL/ SLIDE	Other	Free	+Effort	Ground	Let go
THROW	Other	Free	+Effort	None	Let go
PUSHED	Other	Controlled	+Effort	Ground	See/Hold
CARRIED	Other	Controlled	+Effort	Mover	See/Hold
JUMP	Itself	Free	+Effort	None	Self Movement
A FLOAT	No Prevention	Free	-Effort	None but not needed	Let go
B FLOAT	Air	Free	-Effort	Mover	See/Hold

The features of difference are translated into a numerical score as shown in Table 12.2 from which predictions can be made as before, about the differences between pairs of motion e.g. FALL and WALK will be seen as very different because they differ in respect of all five features between them as do PUSH and FALL. However, THROW and ROLL will be seen as rather alike as they only differ in respect of one.

Table 12.2: The number of features which are different between the nine classes of motion (derived from table 12.1)

	WALK	FALL	FLY	ROLL	THROW	PUSHED	CARRIED	JUMP	FLOAT
WALK									
FALL	5								
FLY	1	5							
ROLL	3	3	4						
THROW	4	2	4	1					
PUSHED	2	5	3	2	3				
CARRIED	3	5	3	3	3	1			
JUMP	2	3	2	3	2	4	4		
FLOAT (A)	5	1	4	3	2 or 3	5	5	4	
FLOAT (B)	5	3	5	4	4	4	3	4	3

The derivation of differences between stereotypical motions from primitive actions, has led to a new set of predictions about the degree of differences which should be seen by children between the classes of motions and how the pairs of motions should be ranked. It would be of interest to see how well these new predictions match the empirical data.

12.4 SYNOPSIS OF RESULTS OBTAINED FROM THE COMPARISON OF NEW THEORETICAL PREDICTIONS WITH EMPIRICAL DATA

The empirical data used was from Matching Task 1. The mean score from the total sample was ranked with the revised theoretical scores and then each individual age group was compared with the theoretical score. The results are summarised in the tables 12.3 and 12.4 below.

Table 12.3: Spearman Correlations obtained with new theoretical position; plus 'identities'

n = 49
n = 36

	Sevens Rank	Tens Rank	Twelves Rank	Fourteens Rank	Sixteens Rank	Mean Rank
+ Identities	0.647	0.673	0.701	0.745	0.775	0.754
- Identities	0.237	0.452	0.401	0.502	0.566	0.504

The correlations including identities are all relatively high as shown in table 12.3. It appears upon first inspection that there is a tendency for the correlations to improve with the age of the children tested but it must be remembered that an animacy factor has not been included at this stage. The scatterplots indicate that the identities form a close group with the exception of the WALK and CARRY comparisons. The scatterplot of the mean versus theoretical score shows that the comparisons which were predicted as the most dissimilar were indeed seen in this way by the children. (See Appendix IX for scatterplots).

The correlations are appreciably less good when the identities are removed. The result of the seven year olds drops more than for any of the other ages,which points to either a weakness in the general structure of the model or to the fact that a particular piece of it is missing. The latter explanation seems to be the most likely because when a factor for animacy is added the correlation, minus identities, improves from a value of 0.237 to 0.793. This result also suggests that animacy plays a more important role in the youngest children's decisions about motion but is still a necessary consideration for all ages since there is an improvement in all the correlations with the addition of an animacy factor.

Table 12.4: Spearman Correlations obtained with new theoretical position; plus and minus identities with an animacy allowance

n = 49
n = 36

	Sevens Rank	Tens Rank	Twelves Rank	Fourteens Rank	Sixteens Rank	Mean Rank
+ Identities	0.676	0.775	0.806	0.877	0.853	0.840
- Identities	0.793	0.558	0.549	0.615	0.687	0.635

12.5 THE COMPARISON OF CORRELATIONS FROM THE PREVIOUS AND REFORMULATED THEORETICAL MODELS

The correlations between the old and new theoretical predictions (including the comparison of identites) are illustrated in Table 12.5 below. There is an improvement in all the correlations for each age group except the seven year olds. These results indicate that the performance of the sixteen year olds matched the predictions better on this type of task. The sixteen year olds certainly have a better memory than the youngest children, they are less impressed with particular accidental features in the pictures and might also be actively seeking to produce consistent results.

Table 12.5: Comparison of correlations from the old and new theoretical models

	Sevens Rank	Tens Rank	Twelves Rank	Fourteens Rank	Sixteens Rank	Mean Rank
New Model						
+ id + anim	0.676	0.775	0.806	0.877	0.853	0.840
-id + anim	0.793	0.558	0.549	0.615	0.687	0.635
-anim -id	0.237	0.542	0.401	0.502	0.560	0.504
-anim + id	0.647	0.673	0.701	0.745	0.775	0.754
Old Model						
+ id + anim	0.740	0.737	0.795	0.836	0.829	0.813
-id + anim	0.399	0.517	0.561	0.665	0.623	0.579
-anim -id	0.292	0.318	0.278	0.513	0.406	0.344
-anim + id	0.680	0.620	0.655	0.750	0.720	0.698

id = identities + = plus
anim = animacy allowance - = minus

12.6 MULTI-DIMENSIONAL SCALING

12.6.1 Introduction

A further statistical analysis was applied to the revised version of the model in order to inspect structural relationships between the stereotypical motions, when defined both theoretically and empirically with the different aged subjects. This technique attempts to predict a statistical structure and so provides a stronger check than has been previously applied to the model. A multi-dimensional scaling method was chosen to construct a geometrical representation of the data in a Euclidean space of two dimensions. The essential ingredient defining all multi-dimensional scaling methods is the spatial representation of data structure. The amount of data would only support two dimensions (there was not enough data to try three or more dimensions) yet in two dimensions there was quite a good fit and the results lend themselves to a reasonable interpretation.

12.6.2 Procedure

Six matrices were constructed of the dissimilarity judgements for all pairs of comparisons of the nine different stereotypical motions. A four point scale was used to represent their judgements. Five of these matrices presented the different ages of the subjects tested i.e. 7, 10, 12, 14 and 16 year olds and the sixth matrix described consisted of the reformulated theoretical description with an animacy allowance.

Analyses of these data were carried out to:-

a. See if the theoretical predictions fitted an interpretable two dimensional representation.

b. See if the subjects dissimilarity judgement of the different age groups tested fitted an interpretable two dimensional representation.

c. Obtain information about how different the subjects dissimilarity judgements were from those predicted by the model, and

d. Identify attributes of the classes of motion to which subjects pay attention when making dissimilarity judgements.

The scaling analyses were carried out using the ALSCAL and INDSCAL program in the SPSS statistical package.

The initial analysis of each subject age group was directed towards determining whether the configuration shown in Figure 12.5 (the theoretical description) adequately represents the different aged subjects' judgements. The second analyses using the INDSCAL program analysed all the empirical data from the five age groups tested. A value of 'weirdness' is calculated which gives a measure of the importance of each dimension to each subject group and provides a picture of the combined data. The adequacy of the various MDS models was determined by comparing the fit indices of constant dimensionality across models. The measures of fit reported by ALSCAL amd INSCAL are presented in tables 12.6 and 12.7 below. The root Mean Square (RSQ) values are the proportion of variance of the scaled data which is accounted for by their corresponding distances. The STRESS measure is Kruskal's normalised measure of residual variance defined on the Euclidean distance and the disparities. Since STRESS is a measure of unexplained variance, smaller values indicate a better fit. On the other hand, as RSQ increases, the fit improves. MDS can recover spatial relations, but only up to rotation, reflection and inversion. In the figure, MDS maps have been rotated, reflected or inverted as necessary to obtain the closest match with one another.

12.6.3 Results

Table 12.6: Fit Indices for Scaling Analyses with ALSCAL model in two dimensions

MATRICES	INDEX	
	RSQ	STRESS
1. Theoretical prediction	0.936	0.09
2. Seven years	0.75	0.21
3. Ten years	0.904	0.117
4. Twelve years	0.736	0.19
5. Fourteen years	0.815	0.16
6. Sixteen years	0.797	0.161

Table 12.7: Fit Indice for Scaling Analyses with INDSCAL model in two dimensions

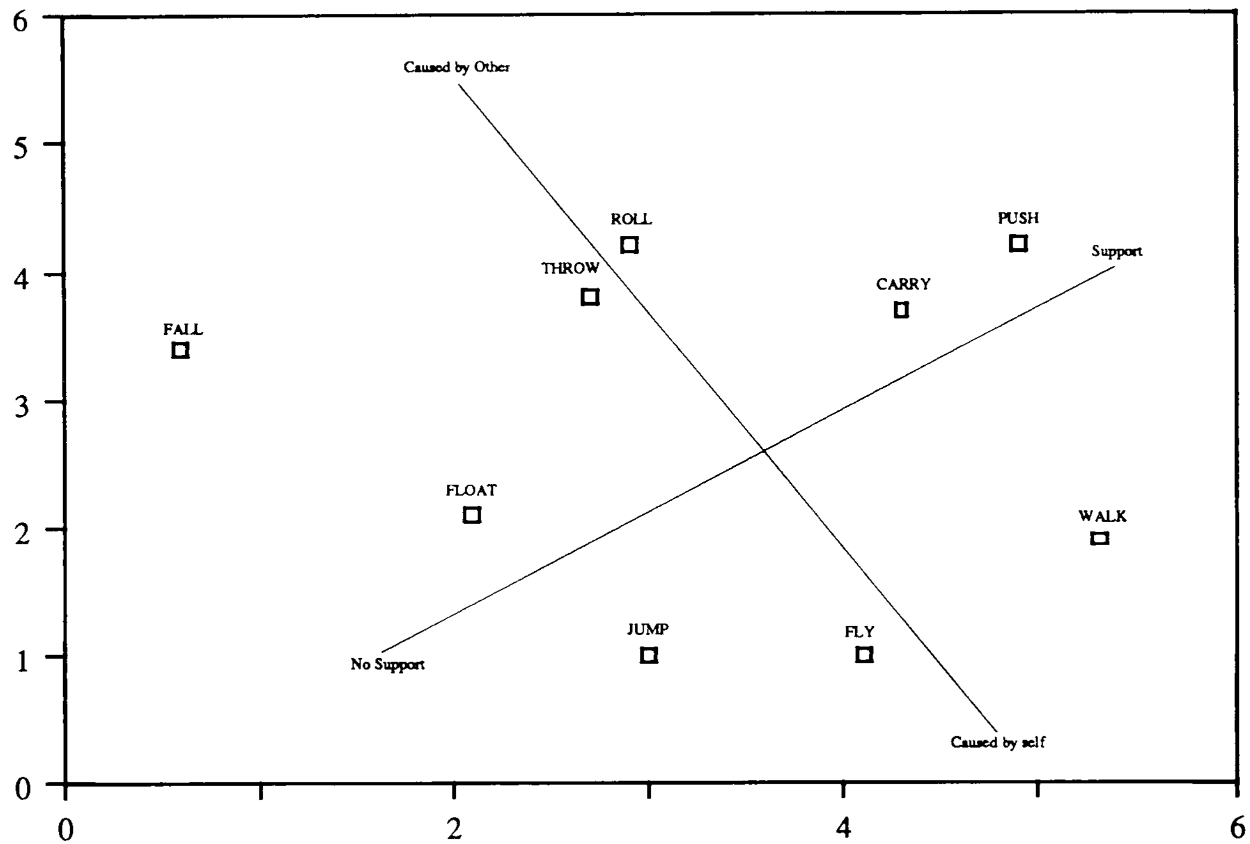
MATRICES	INDEX	
	RSQ	STRESS
1. Combined all ages	0.695	0.207

12.6.3.1 General Overview

By far the most striking result of this analysis is how well the dissimilarity judgements can be represented in terms of a two dimensional model. In general judgements of dissimilarity among these stereotypical motion stimuli can be interpreted as more strongly influenced by the nature of the support and the cause of motion i.e. whether self activated or with the effort supplied by another agent. Closer inspection of the individual age group representations demonstrate deviations from the theoretical predictions, with the sixteen year old data providing the best fit.

FIG. 12.5: THEROETICAL MDS MAP

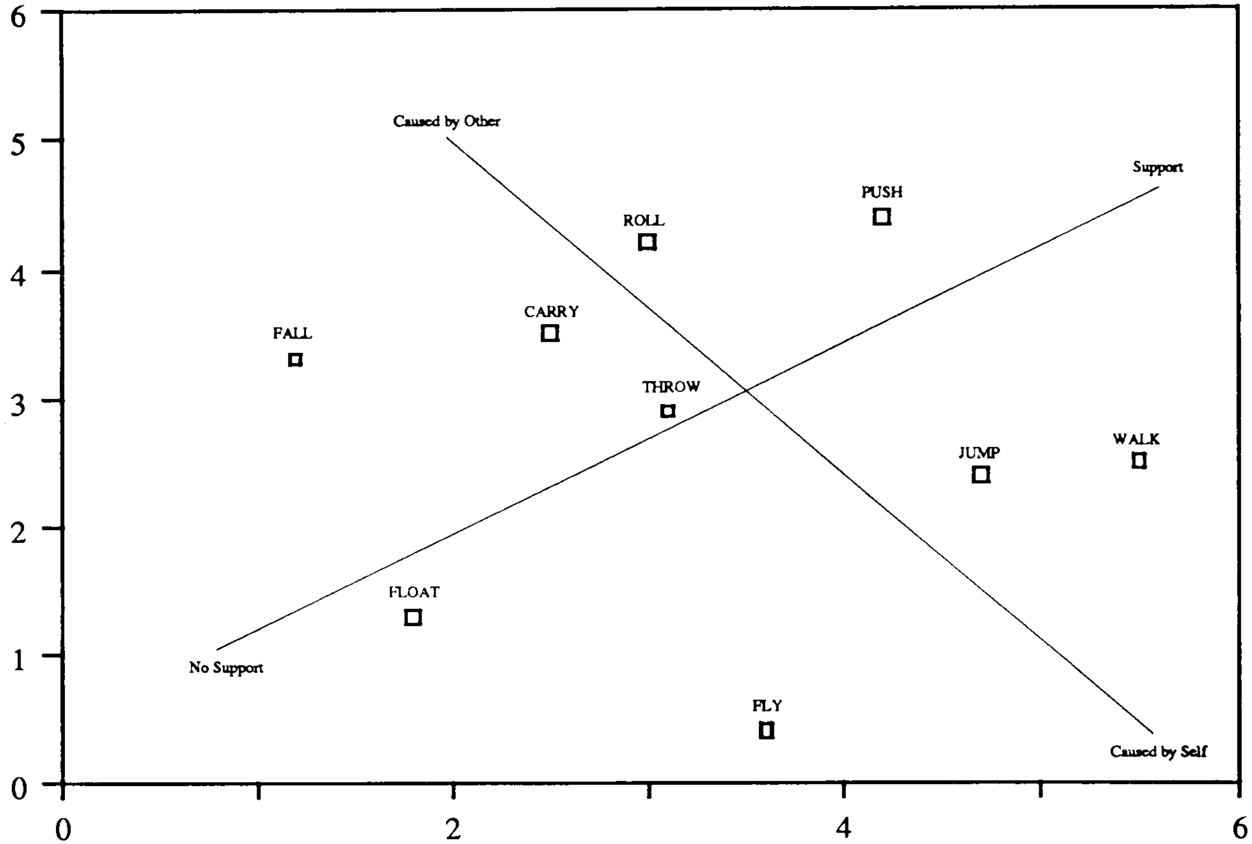
Dim. 1 Horizontal Dim. 2 Vertical



Dim. = Dimension

FIG. 12.6: SIXTEENS' MDS MAP

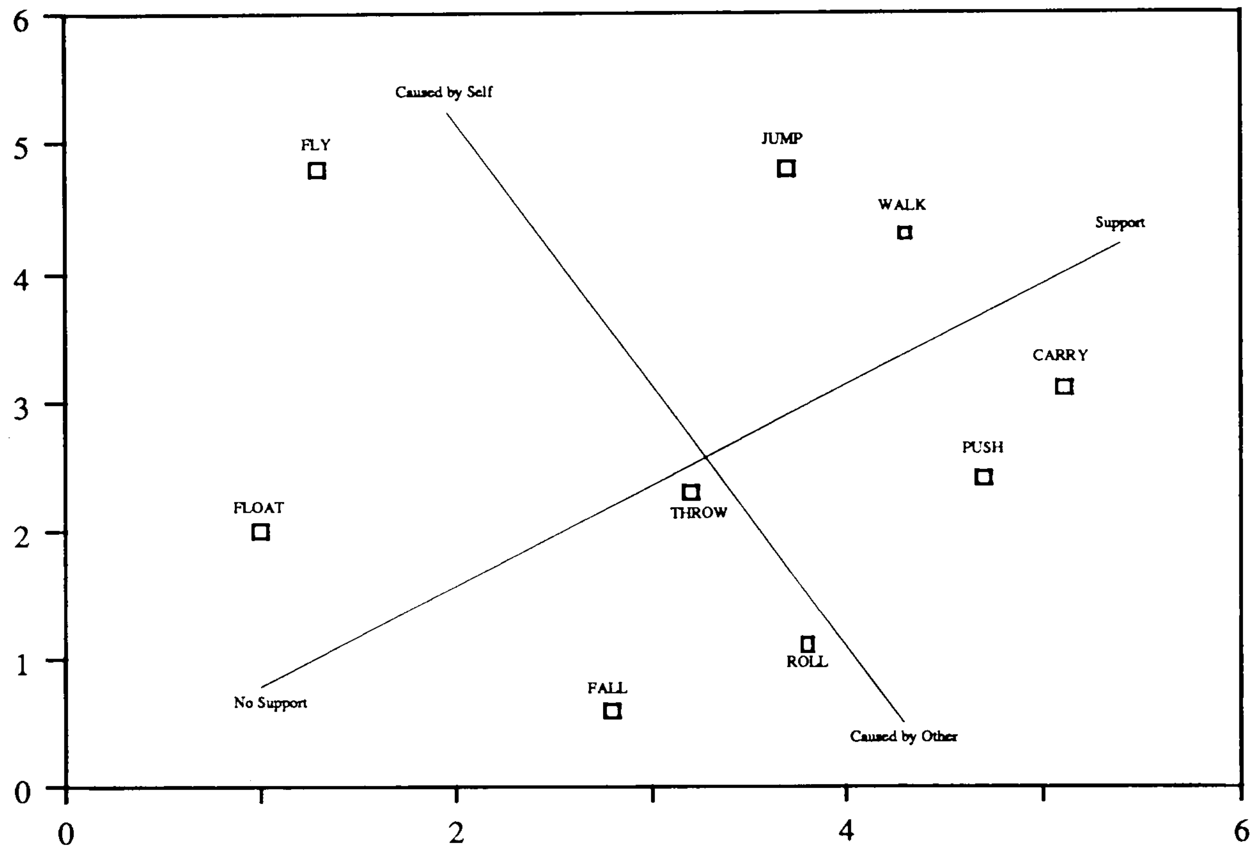
Dim. 1 Horizontal Dim. 2 Vertical



Dim. = Dimension

FIG. 12.7: FOURTEENS' MDS MAP

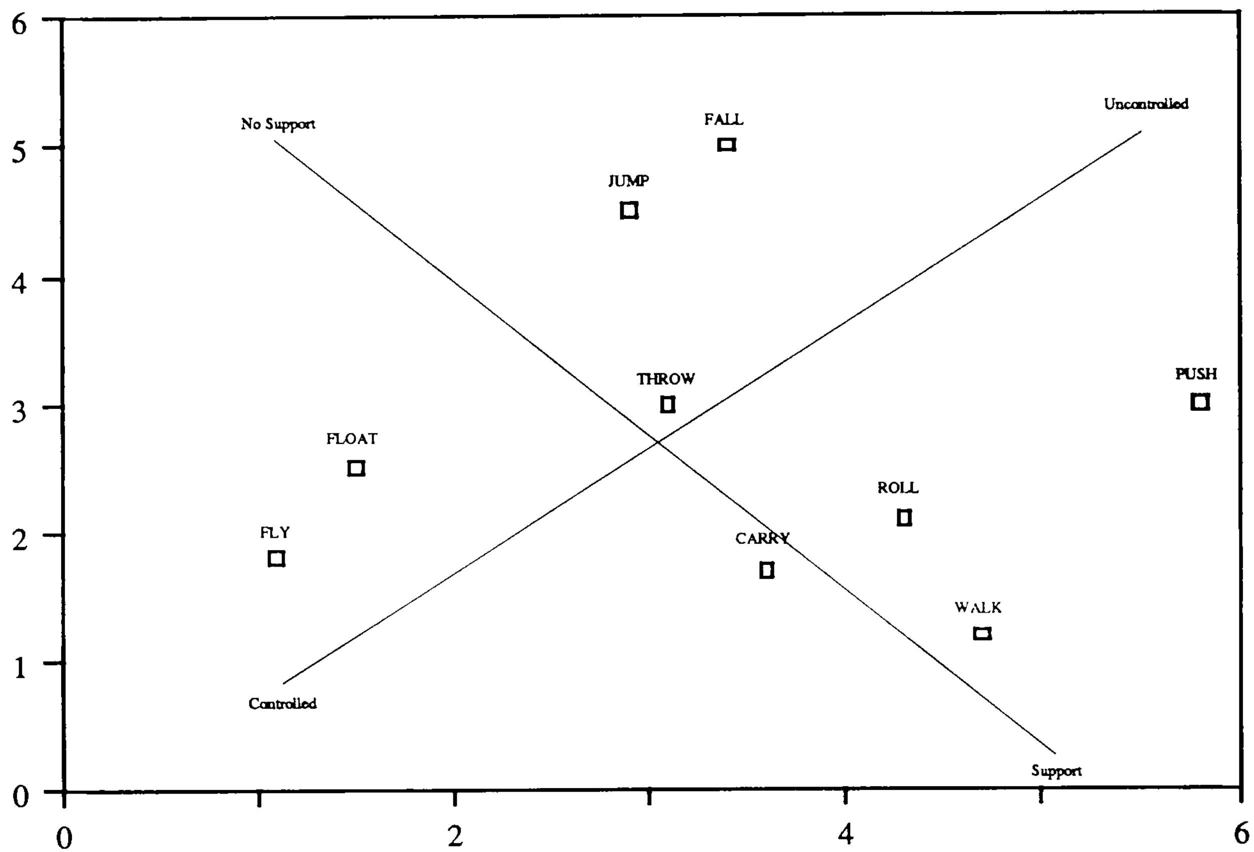
Dim. 1 Horizontal Dim. 2 Vertical



Dim. = Dimension

FIG. 12.8: TWELVES' MDS MAP

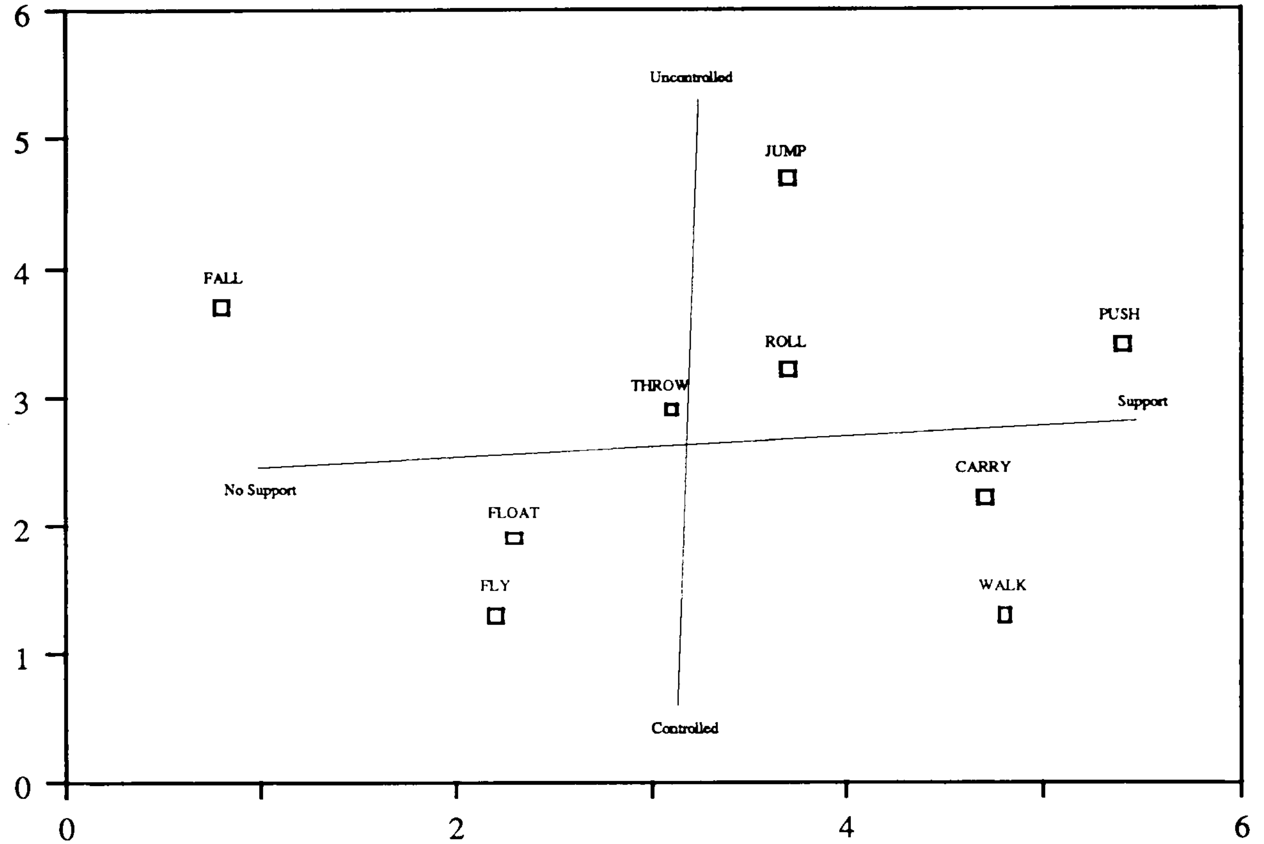
Dim. 1 Horizontal Dim. 2 Vertical



Dim. = Dimension

FIG. 12.9: TENS' MDS MAP

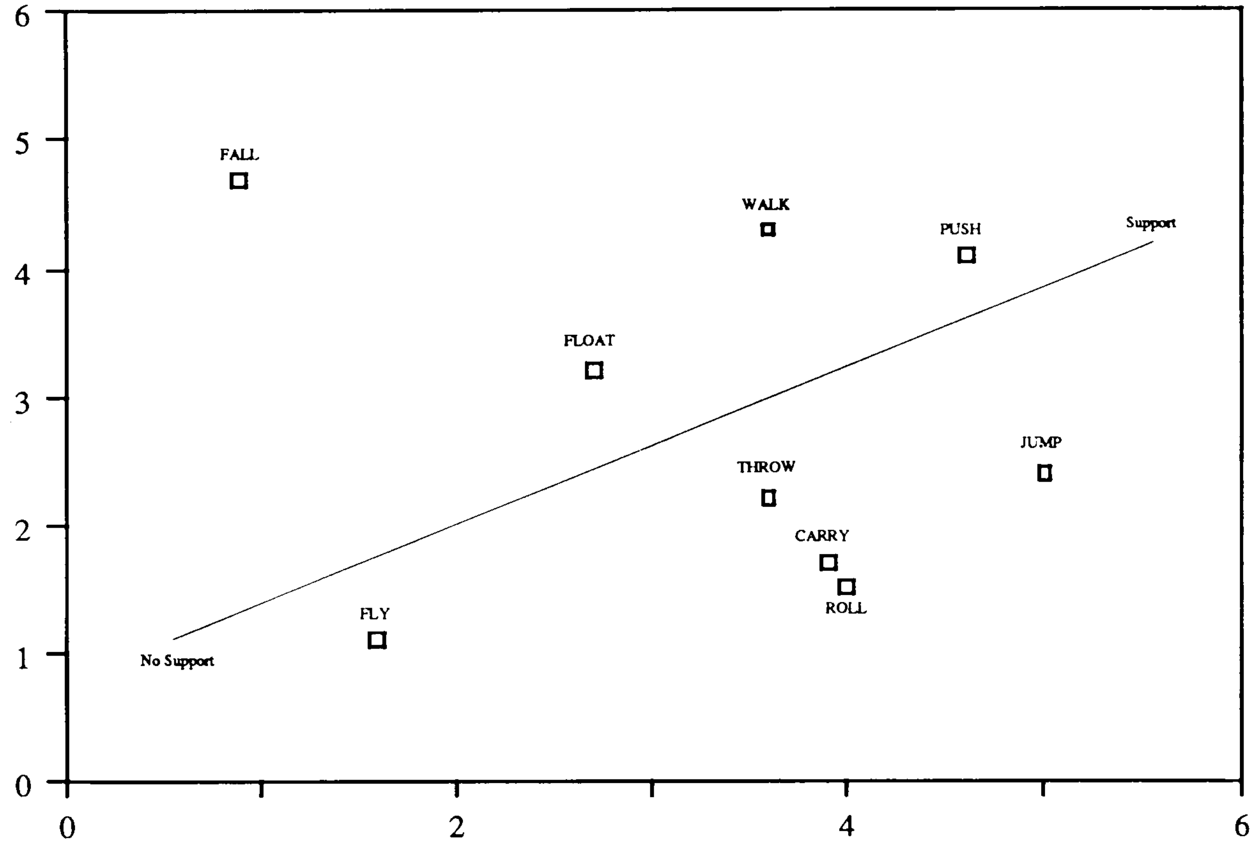
Dim. 1 Horizontal Dim. 2 Vertical



Dim. = Dimension

FIG. 12.10: SEVENS' MDS MAP

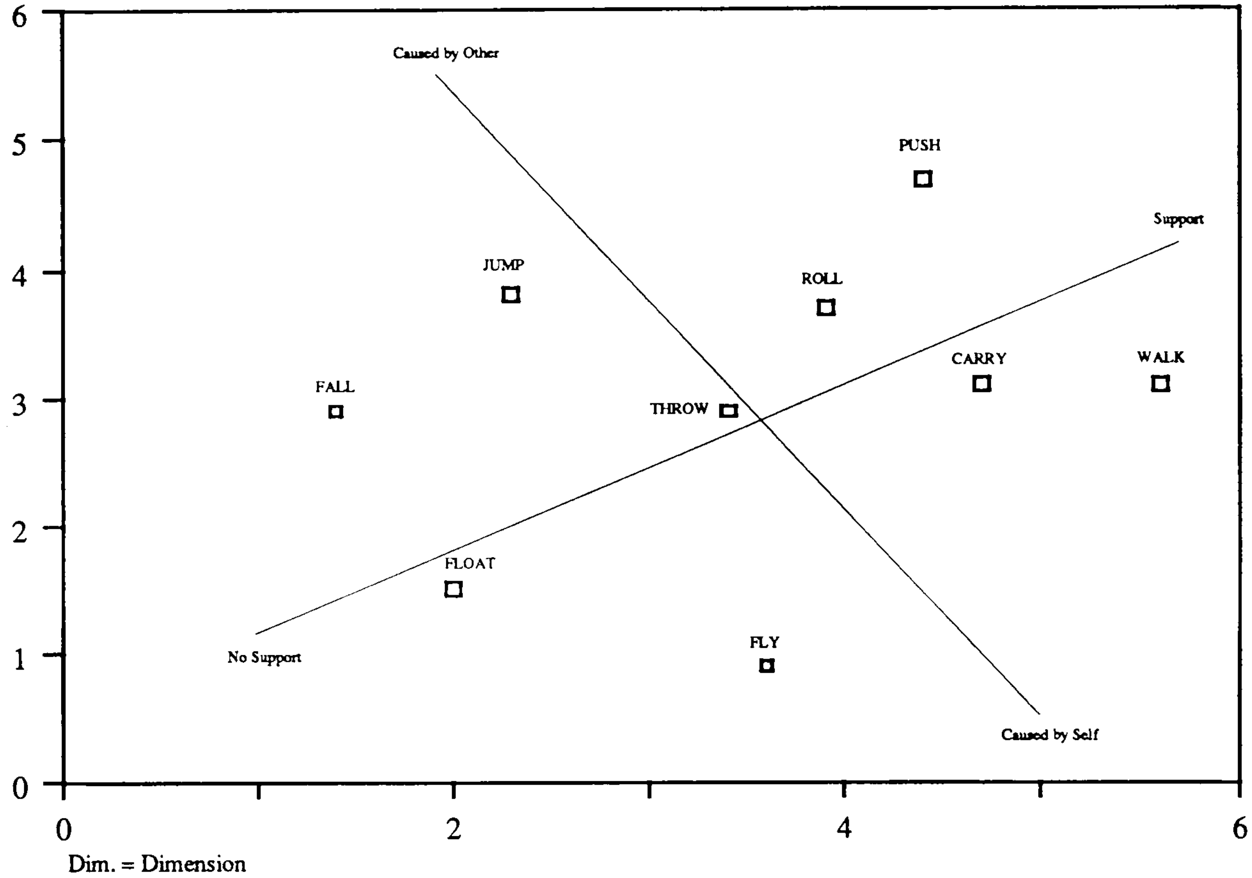
Dim. 1 Horizontal Dim. 2 Vertical



Dim. = Dimension

FIG. 12.11: COMBINED AGES MDS MAP

Dim. 1 Horizontal Dim. 2 Vertical



12.6.3.2 Overview of MDS space for Theoretical Predictions

The points described by the theoretical matrix can be interpreted (see Figure 12.1) as a two dimensional map. The model predicts that pupils will use properties such as support and cause to separate the nine stereotypical motions and in fact Dimension 1, the horizontal axis, can be interpreted as SUPPORT and NON SUPPORT and dimension 2 the vertical axis can be described as representing the notion of SELF CAUSE or CAUSED BY OTHER.

Upon inspection of the theoretical map the only motions which are SELF CAUSED are found in the lower half of the graph and these are JUMP, FLY and WALK. They are separated in space by a difference in their support. WALK and JUMP are found at the extremes of dimension 1 while FLY is found in the middle which indicates FLY's support is an intermediate of the other two. The model predicts that FLYs support is provided by itself through its own effort.

All motions which are not supported and are caused by another source are found in the upper left hand quadrant of the graph. These are FALL, FLOAT, THROW and ROLL. While the supported motions caused by an agent are found in the upper right hand quadrant. The fit indices of RSQ 0.936 and stress 0.09 indicate how well the theoretical predictions are represented in terms of a two dimensional model.

However, there is an anomaly presented by this theoretical description and that is the position of FALL. In the theory the role of an agent letting go of something is very different from that of an agent directly causing a motion through effort.

12.6.3.3 Description of MDS space for sixteen year old data

The stress of 0.16 and RSQ of 0.8 indicates that the empirical data is well represented by a two dimensional map, and like the theoretical representation these dimensions can be interpreted as SUPPORT/NONSUPPORT versus SELF CAUSE/CAUSED BY OTHER. The sixteen year olds data provides the best match with the theoretical predictions.

However, FLY, JUMP, CARRY and FLOAT least fit the theoretical predictions (i.e. they appear in different quadrants of the map to the theoretical points).

i. FLY - The subjects response indicates that the motion is unsupported yet provided by self. However, the theoretical prediction recognised support supplied by the motion itself, i.e. with a bird the theory says the motion itself provides the support. It looks as though the subjects don't interpret a FLY motion in quite this way.

ii. CARRY - In the sixteen year olds representation CARRY is found in the top left hand quadrant rather than in the top right hand quadrant of the map. The empirical data differs from the theoretical prediction with respect to dimension 1 i.e. SUPPORT. It appears that the subjects recognise CARRY more as an unsupported motion.

iii. JUMP - The subjects disagree with the theoretical prediction in respect to dimension 1. The results suggest that they see JUMP more like a supported self motion rather than an unsupported self motion. JUMP is found much closer to WALK on the multi-dimensional scaling map which suggests the subjects recognise JUMPING more like WALKING in the air rather than THROWING yourself into the air (see section 11.1.3).

iv. FLOAT - is found just in the lower left hand quadrant of the map suggesting it is viewed more as an unsupported self caused motion rather than an unsupported movement caused by an agent.

12.6.3.4 Description of MDS space for fourteen year old data

The stress of 0.16 and RSQ of 0.815 indicates the data is well represented in two dimensions. Again a good fit is found between the fourteen year olds data and that of the theoretical predictions. FLY, JUMP and FLOAT least fit the theoretical predictions and are found in similar positions to those of the sixteen year olds which means a similar interpretation can be placed on these results as already described for the sixteen year olds in section 12.6.3.3 above.

12.6.3.5 Description of MDS space for twelve year old data

The stress factor is still quite low 0.19 but the RSQ indicates that only 73% of the variance is accounted for by this representation. In order to make sense of this map dimension 1 can still be interpreted as SUPPORT versus NON SUPPORT but dimension 2 is now more like controlled versus uncontrolled action. This new interpretation of the dimension 2 still gives rise to some anomalies which are the positions of FLOAT, and WALK. FLOAT is viewed as a controlled but unsupported action, while WALK is seen as an uncontrolled yet supported motion.

12.6.3.6 Description of MDS space for ten year old data

The ten year old model has a high RSQ of 0.904 and a stress factor of 0.117 which indicates a good representation of the data in two dimensions. If the two dimensions are interpreted in a similar way to the theoretical map namely as support/non support and caused by self/ caused by other then JUMP, FLOAT, CARRY and FLY motions do not fit the theoretical predictions. The dimension of own cause/other cause is better described as controlled/ uncontrolled motion and then the predictions made by the subjects is more reasonable. This result is an indication that the twelve year olds and ten year olds view the differences between the stereotypical motions in a similar fashion to each other which differs from that of the theoretical model.

12.6.3.7 Description of MDS space for seven year old data

It is more difficult to see clearly what descriminations the subjects are making in this two dimensional representation. It appears that only one dimension has a reasonable interpretation namely Support. This map only accounts for 75% of the variance.

12.6.3.8 Overview of the MDS space for Combined Ages

This map was produced by combining the matrices from all the ages tested. The map of combined ages indicates that seven of the nine stereotypical motions are placed in the same quadrant of the graph as predicted by the theory. Interpreted in terms of the dimensions of SUPPORT/NONSUPPORT, OWN CAUSE/CAUSE BY OTHER then the subjects appear to agree that -

i. FLY and FLOAT are motions with their own cause and no support.

ii. FALL and THROW are motions with another cause and no support.

iii. ROLL and PUSH are motions with another cause and support.

iv. WALK is a motion with own cause and support.

However on this interpretation CARRY is described as a motion with its' own cause and support. The examples chosen to represent CARRY were a man carrying a pole and a train carrying passengers. Both sources of motion of the carried objects were autonomous in nature and hence were representatives of "own causes of motion".

JUMP is seen as a motion that is not supported yet caused by an agent. This is not such a strange result as first appears since as discussed in section 11.1.3 some of the pictures which represented JUMP were closer to a FALL type motion.

It must be recognised that the fit is poorer for the combined data than for any other representation. The graph only fits 69.5% of the variance. From the weirdness values the seven and ten year olds give more importance to dimension 1 the SUPPORT of motion rather than to 2 the cause of the motion.

12.6.4 Discussion

All the MDS representations have one dimension which can be interpreted as motion taking place in the air or on the ground. The other dimension can be interpreted as to do with cause. Cause can be produced by an agent or by the object itself and is the other important distinction predicted by the theoretical model. The MDS representations fit the theoretical predictions reasonably well however, dimension 2 needs to be interpreted as control versus non control for the ten and twelve year olds map. The pattern produced for the seven year olds fit the least well, where only one dimension can be interpreted which is SUPPORT versus NON SUPPORT. With the sevens model a similar result would have been produced if this year group were using more than two dimensions. This would mean they were paying attention to particular features in the pictures as argued before in section 11.1.3. Some problems occurred with interpretation of JUMP and this could be the fault of the pictures which were selected to represent this motion. However it is reasonable to suggest that the models prediction of JUMPING being considered as more like WALKING in the air rather than being THROWN into the air is correct. It appears that FLYING is viewed more like WALKING in the AIR rather than being CARRIED in the air while FLOATING cannot be interpreted as being closer to a FALL or a CARRY motion from this set of data.

12.7 A POSSIBLE DEVELOPMENT OF ANIMACY

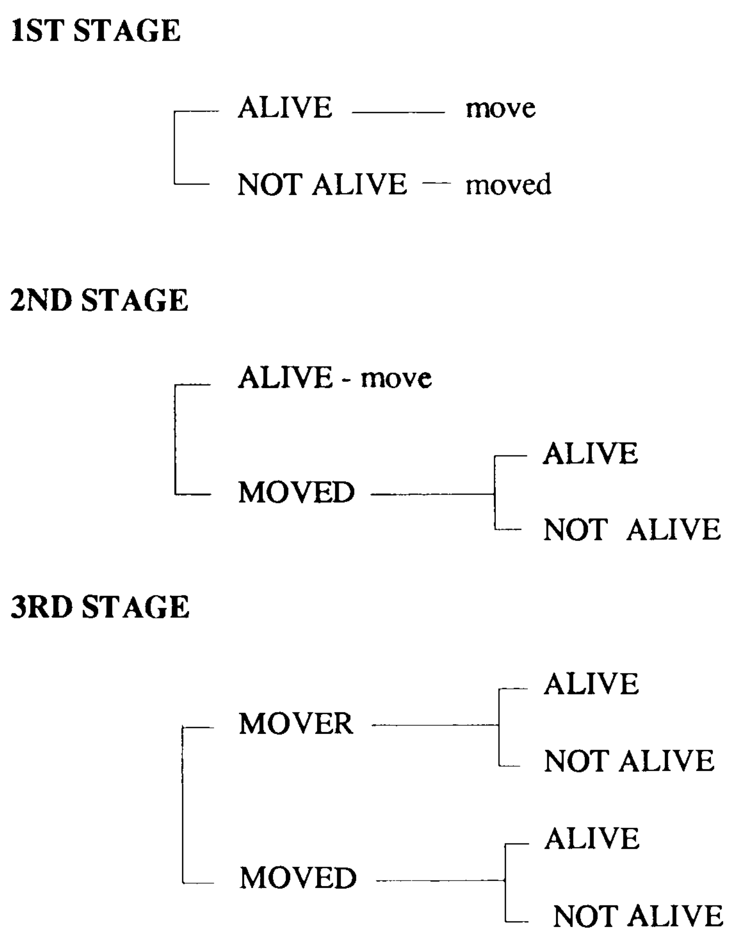
The correlations indicate that it is not so wise to add the same factor for animacy to all the age groups tested and in fact a proper account of animacy should include some developmental hypothesis. This would mean that different ages received differing adjustments with respect to animacy. Although I do not wish to present a full developmental analysis of this feature an outline of its possible genesis is described below.

The child's actions during the sensori-motor period only start to lay the foundations of distinctions made between objects which can move themselves and others which require external agents to cause their displacement. Children recognise living things by their ability to move on their own. This could be a first stage in an understanding of animacy.

Figure 12.11 below speculates about the development of the notion of animacy and suggests that a second stage in the notion of animacy iswhere objects which are moved by external agents are recognised as being able to be alive too.

By the time the third stage is reached the mover can also be alive or not alive. During the early stages of this understanding errors of judgment would probably take the form of a projection of animate properties onto inanimate objects. (N.B. These ideas can only occur when the child is able to symbolise an ability which does not appear until about eighteen months. Therefore only the beginnings of notions about animacy could be suggested as developing during the sensori-motor period). There are still questions about animism and its derivation to be answered in terms of the model and this third version draws further attention to these problems.

Figure 12.12: Possible development of ideas of animism related to motion



12.8 FUTURE RESEARCH

This thesis has shown that a simple task, administered to a wide age range of subjects, which just counts features of difference between motions can in some sense account for subjects conceptions of causes of motion. Although the theoretical model has now been adapted there is a limit to the amount of progress that can be made to this type of reformulation and so in order for the work to advance what sorts of avenues merit exploration? A developmental model could be proposed with a different representation for various ages. However, this is not the only way forward. Another model could be produced which takes account of the varying agreement of features per motion. A possible candidate for this representation is that of FRAMES, (Minsky, 1975). I do not propose to discusss in this thesis, the details involved in this line of research but possible sketches for probable frames are found in Appendix IX. A frame representation could provide a possible starting point for future work and allow questions about how a series of expectations about certain motions are built up into a scene. Figure 12.6 proposes a possible set of expectations which are derived from the following four questions:-

1. What changes the object's position from rest?

2. How does this change come about?

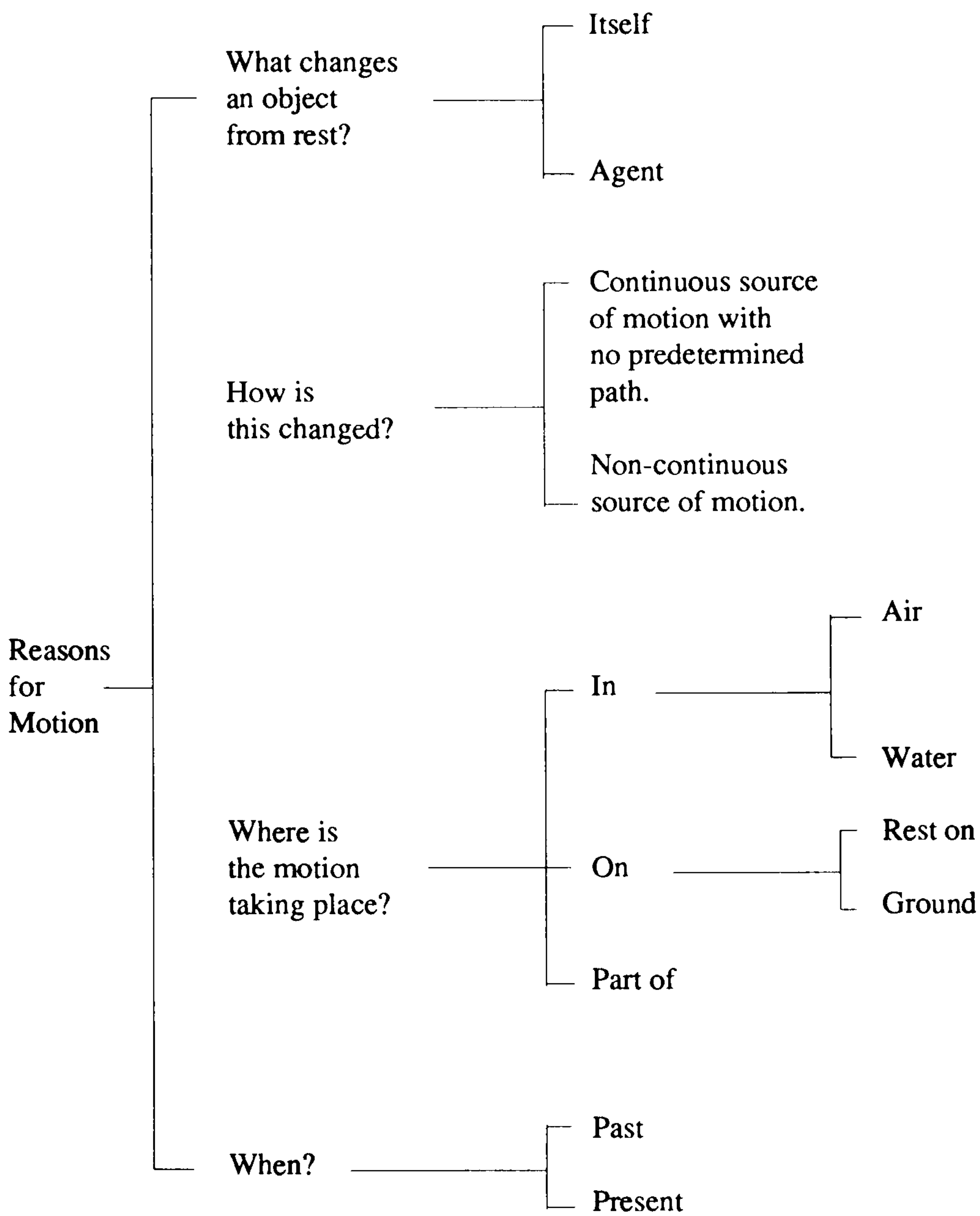
3. Where is the motion taking place?

4. When did the action occur?

If these questions are answered then decisions about the reasonableness or likely occurrence of certain types of motion can be made. Pupils in the interview study (see chapter 5) were able to explain very quickly why certain actions completed by cartoon characters could or could not happen in real life. The frame representation couldnot only be used to describe a series of expectations about each stereotypical motion but also to construct a series of expectations about a number of different motions in a scene.

These are also the sorts of ideas which might be considered in the next phase of a prolog version of a commonsense model of motion. The concluding remarks together with suggestions for a more fundamental reformulation of the model are discussed in chapter 13.

Figure 12.13: Network to show how we possibly construct a series of expectations about motions in a scene



13. CONCLUSIONS

This final chapter is in four sections. 13.1 **Overview of the research** describes what has been achieved in this thesis. 13.2 **Summary**, answers the research questions posed in chapter 4. 13.3 **Suggestions for improving the model**, indicates a need for some type of developmental account of motion while 13.4 **General issues** raises matters which deserve further investigation.

13.1 OVERVIEW OF THE RESEARCH

Previous research into children's ideas about physical phenomena has shown that these ideas are very different from those of the scientist. The area of dynamics has produced a large body of research data, mainly particular descriptive accounts of children's reasoning, which are not always easy to interpret. There is also a difference of opinion about how these conceptions should be viewed. That is, whether children's ideas in dynamics should be described as systematic mental structures or as adhoc temporary constructions. It is not easy, however, to see how to empirically test the merits of these different positions. This thesis set out to test a particular theoretical hypothesis about the content and nature of commonsense reasoning about motion.

A first version of a model of commonsense thinking about motion was proposed by Ogborn (1985) with ideas derived from Hayes' (1979) "Naive Physics Manifesto". It provided a moderately clear theoretical account of how children could think about the causes of motion using two primitive motions, support and effort. The first phase of the research was to explore the use of two different methodologies:-

i. An interview technique and

ii. A repertory grid technique

In separate pilot studies to test this theoretical account both techniques suggested that children understood motion in terms of the major components of the model i.e. they discussed different types of motion in a way that could be interpreted as using the primitives of Support and Effort. However, the repertory grid method provided not only a more systematic testing of the theoretical account than the interview study but also proved to be a more successful way of exploring a model constructed of generalisations, since this methodology required subjects to make such generalisatons in order to classify different examples of types of motion. An important distinction found with this technique used by the subjects and not mentioned by the model was that of animate/inanimate motion.

The results of these two studies helped in the modification and improvement of the theoretical account which led to the construction of a formalised second version of the model which aimed to describe the sorts of motions which people naturally use in order to make comparisons. This second version, still based upon ideas from Piaget, suggested that early ideas about motion are formed through action. The formalised model used an analysis of causation to provide its basic structure which was expressed through a series of systemic networks.This causal framework clearly explained the link between Effort and Support and gave rise to a description of nine stereotypical motions. More importantly this version of the model defined the differences between these motions. It provided a number of testable hypotheses about tacit conceptions of motion, by specifying stereotypical motions and predicting differences between them. Hence a matching task which assessed the features of difference between these stereotypical motions suggested itself as a methodology for the main study.

A Matching Pairs Paper and Pencil Task was developed for the main study, in which subjects, aged between 7 and 16 years, were asked to distinguish between examples of the nine stereotypical motions, comparing the differences between the causes of these motions. Two supplementary tests were carried out to

i. Clarify the role of motions in which one object carries another

ii. Assess the importance of the role of animacy in deciding differences between motions.

The results from the main Matching Task showed that responses could be predicted to some extent by the model. There was however an improvement when an animacy feature was taken into account. It also appeared, as the model predicted, that the movement of a CARRIED object is perceived as part of the motion of the CARRIER. However in the theory objects which inherit their support and effort from other objects are not necessarily considered alike as regards to motion. There are three further distinctions within the CARRY paradigm which predict that objects which are fixed to a CARRIER should be seen as different from objects which form part of or are CARRIED-IN or CARRIED-HELD by the CARRIER. Although the PART-OF distinction was not tested in this study the results show that subjects perceived a difference between the movement of objects which were CARRIED IN or CARRIED HELD by the CARRIER. The results indicates that the type of attachment or support between pieces of a scene could prove to be an important consideration in the perception of objects and their motion.

The systematic testing of animate/inanimate comparisons indicated that children do consider animacy to be an important distinguishing feature as regards motion. A better match was found between the empirical data and the theoretical predictions when a factor of animacy was added. In fact the correlations improved from about 0.6 to 0.8. This result suggests that animacy is a distinction which cannot be neglected by any theoretical account of commonsense ideas about motion.

In the light of the empirical data the commonsense model of motion was again modified and improved by trying to paint a broad picture of the construction of classes of motions from actions. This new version explored the possibility of constructing the stereotypical motions from a set of more primitive actions, incorporating them into a reformulation of a commonsense model of motion, to be tested against the available data. It was possible using the primitive actions of SEE/HOLD, LET GO and MOVE YOURSELF to construct the basic stereotypical motions and when these primitive distinctions were incorporated as an additional feature of difference together with agency, cause, effort and support, the correlations between theoretical predictions and the empirical data further improved. Further statistical analysis was applied to this revised version of the model to see what the spatial relationships were between the stereotypical motions. One striking result is that both the theoretical and empirical data fitted an interpretable two dimensional representation. This is an important finding since it tends to suggest that the revised version can predict in some way the structure of thinking about motion.

13.2 SUMMARY

The commonsense model after testing and modification provides a good account of commonsense causes of motion. It is now possible to provide some answers to the research questions raised in Chapter 4 about the nature and content of a commonsense knowledge of motion.

1. Is this knowledge structured and internally consistent?

The striking agreement between the empirical data and the theoretical predictions across a wide age range is an indication that commonsense knowledge about motion is structured and internally consistent since the data was derived from the systematic testing of an internally consistent model.

2. Has the model clearly defined the primitives of this structure?

It appears that the units or primitives of EFFORT and SUPPORT are central to an understanding of motion and in that sense the model gains support. However notions about animacy are also important considerations in the understanding of movement and are a feature which cannot be omitted from any future model. The identification of three primitive actions from which the stereotypical motions could develop points a way towards a further developmental account of motion, (see 13.3).

3. What holds the pieces of the structure together?

Causality has provided a useful and perhaps necessary framework for the understanding of motion. This is suggested because, following Piaget, if the basic ways of thinking are constructed through action, then action and movement lead to the construction of the notions not only of object, time and space but also of **cause**.

4. Do the ideas predicted by the model appear across a wide age range of subjects?

Correlations were substantial at all ages. However, in general the models predictions were better for the older pupils than for the younger ones and three possible causes of mismatch between the theoretical predictions and empirical data obtained from the younger children are proposed. These are:-

i. Limitation of processing capacity.

ii. Egocentricity.

iii. Concentrating on particular features in the Matching Task and not generalising.

In my opinion the most important reason for the seven year old variability in response is the failure to generalise. In this sense, a model constructed of generalisations is not entirely appropriate.

5. How do such commonsense ideas develop?

The model postulated that ideas about motion are formed through action, and the final revision proposed that these early actions could be SEE/HOLD, LET-GO AND SELF MOVEMENT. This version of the model also suggested that if stereotypical motions were derived from such action schemes then some motions could be considered as more basic than others . This means that ideas about FLYING and FLOATING should be considered as rationalisations from actions such as WALK, CARRY and FALL. It would be important to test if motions are partly identified by their closeness to the earliest actions performed in childhood,since this theoretical proposal suggests that subjects should not only be able to differentiate between stereotypes but should also be able to rank their differences.

13.3 SUGGESTIONS FOR IMPROVING THE MODEL

Certain anomalies still remain with the model, even in its revised form. These include (a) the theoretical status of FLOAT, and (b) that all the features of difference between the stereotypical motions carry the same weighting. The above problems together with the proposals which have already been suggested in sections 12.7 and 12.8 to improve the model illustrate a need to build some developmental theory. The primitives of any new model need to explain how the following features are understood:

1. Objects and their properties.

2. The space occupied by these objects.

3. The notions of effort and cause, and

4. Ideas about time and its change - since motion is an alteration in time and space.

Therefore, integral to the child's knowledge of motion are his ideas about time, space and causality.

It is Piaget's early work on the sensori- motor period, which includes descriptions of how the child constructs not only the object concept but also the notions of space and causality, which deserves further attention here. Tables 13.1 and 13.2 summarises some of this work.

Figure 13.1 suggests how Piaget's findings can be used to construct six of the stereotypical motions. It is through the manipulation of objects by for example holding them and moving with them, the child becomes aware of a world made up not only of moving and moveable but also fixed objects. These activities also create the idea of space in the young child, as she/he becomes aware that there are objects and that there are also gaps between these objects. These include obstacles which are too large or heavy for us to move ourselves. Thus the world is made up of things which are able to move themselves, and other things; there are also fixed objects which cannot be moved.

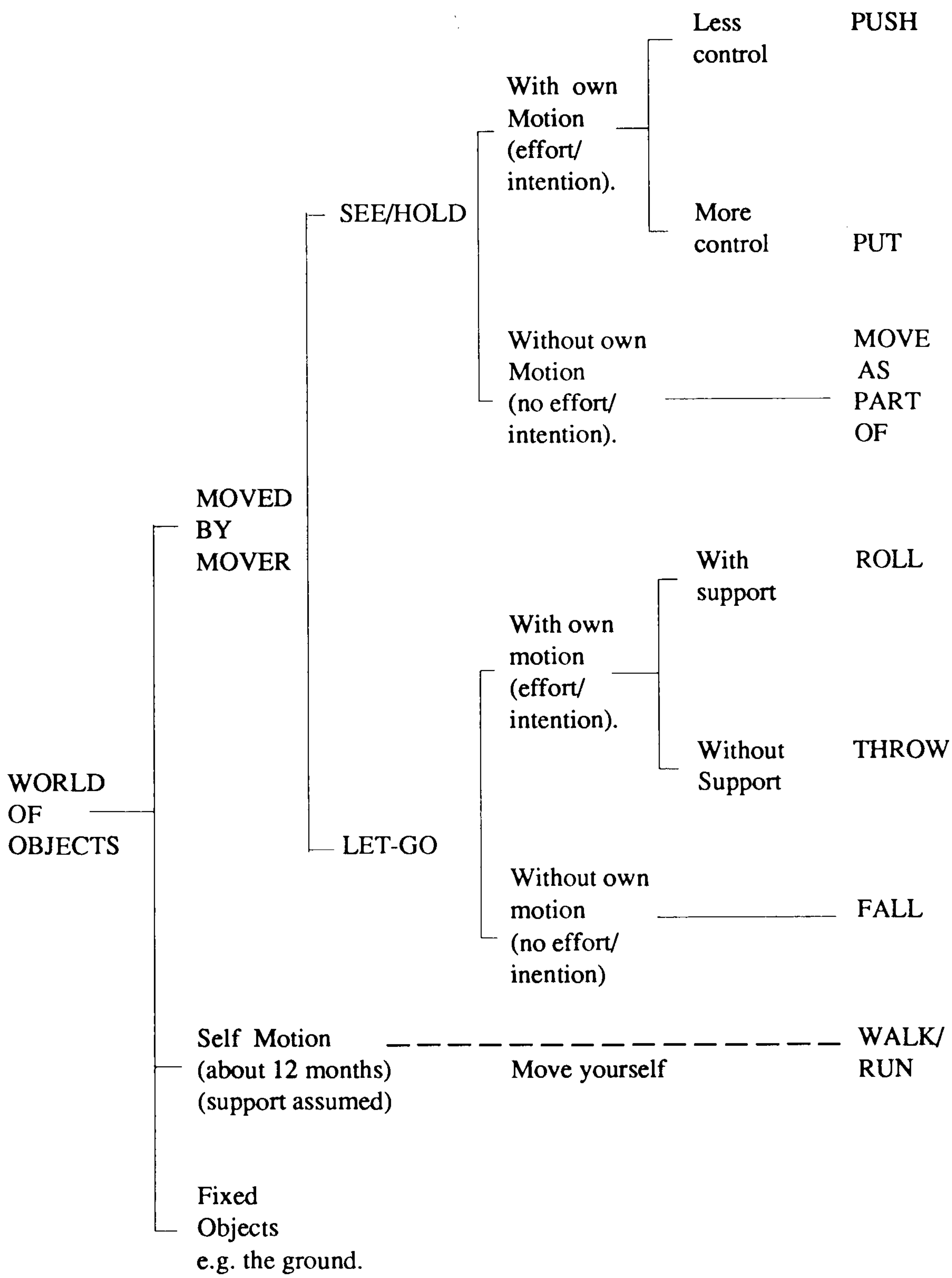
Table 13.1: Table to illustrate the types of actions exhibited by the infant during the sensori-motor period

SENSORI-MOTOR PERIOD	DESCRIPTION
i. (0-1 month)	At birth actions of sucking and grasping exercised within a limited repertoire of actions which include hearing and seeing. Sucks anything that touches lips and grasps any object which touches palms of the hand.
ii. (1-4 months)	Beginning of arm mouth co-ordination - infant able to suck thumb at will. Able to move another object and repeat this movement (primary circular reaction) e.g. move blanket on cot is now becoming aware of objects through their "graspability", “visibility” and "suckability”.
iii. (4-8 months)	Elaboration of grasp relflex. More notice taken of "let-go". Starts to attend to the start of a falling motion. At 5 months when an object is dropped outside the pram she/he only looks at the hand that dropped it but if the child drops the objects she/he views its trajectory. 7 months - searches for objects dropped onto the cot.
iv. (8-12 months)	Actions mainly grabbing, shaking, balancing, hiding and finding things. There is also a big increase in autonomous motion.
v. (12-18 months)	More regularly carries objects from place to place. Puts solid objects into hollow ones places objects on/on top of other objects. Slides objects up and down inclines. No longer just lets things fall to the ground but purposefully throws them down.
vi. (18-24 months)	Connection of actions into events since there is a development of the notion of time. Child is able to notice before and after. Further exploration of properties of objects.

Table 13.2: Table describing the development of the notions of Object, Space Cause and Support during the sensori-motor period (after Piaget)

SENSORI-MOTOR PERIOD	DEVELOPMENT
i. (0-1 month)	World appears as a visual tableaux.
ii. (1-4 months)	Becoming more aware of objects through their "graspability", "visibility" and "suckability".
iii. (4-8 months)	Effort becoming externalised. Increase in reaching and touching other objects, helps to differentiate self and non-self in space.
iv. (8-12 months)	Further development of object concept. Starting to understand effort or cause which pertains to motor action. Noticing effect of causes. Aware of boundaries of objects but still does not realise need for contact between his arm and the moved object. Notion of object tied to previously successful action ie. grabbing, shaking, balancing, hiding and finding. Spatial sense increasing can put objects on other ones.
v. (12-18 months)	More systematic investigation into behaviour. Notion of SUPPORT of objects increases. First conscious attempts to investigate relationship of placed on/on top of. Relationships appear between actions as causes and displacements as results. Notices himself and others as Agents or cause.
vi. (18-24 months)	Object permanence established. Seems to attribute causal power to independent centres e.g. child is able to point to an object it cannot reach and looks at the parent to fetch it.

Figure 13.1: Network to propose a description of how the child's actions of SEE/ HOLD, LET-GO and SELF MOVEMENT not only start to divide the world of objects into those which cannot be moved, move themselves or move other objects, but also give rise to six stereotypical motions described by the commonsense model of motion



There is no direct documentary evidence about the child experimenting with floating objects in the air. The literature instead records the child's experimentation with falling objects. The revised model (see chapter 12) proposed that FLOAT could arise from a LET-GO primitive, because the child is learning about lightness and heaviness through dropping and throwing things around. It is also suggested that FLOAT could develop from the notion of "moving in" or "moving as part of another object". These ideas may start to develop in sensori motor period iv. and progress as the child himself moves objects together i.e. CARRIES toys from one position to another.

Another issue which requires further consideration is the formalism which should be adopted to represent any developmental theory. The network formalism is best adapted to showing the structure of ideas at a moment, so that development is represented as a series of systemic networks. A frame representation might prove to be a formalism which deserves investigation.(see 12.8).

13.4 GENERAL ISSUES

The testing of a model of thinking about motion raises questions of a more general nature such as :

i. Are there more generalised thinking schemes at the root of such models?

In thinking about the developmental aspects of motion, analogical reasoning suggests itself as a general scheme of thinking, e.g. FLYING can be considered as WALKING in the air. These sorts of ideas need to be explored along with how children understand floating objects.

ii. Is causality a useful framework for commonsense thinking?

The present research indicates that causality provides a framework of understanding for motion and it might prove useful to see if it is possible to build causal models of children's thinking in other areas.

iii. Is it possible to construct an ontology of commonsense?

All the versions of the model to date have sought to look for the primitives of reasoning about motion. The present findings suggest that the way towards improving the model is to look at a deeper analysis following Piaget. He proposed that during the sensori-motor stage the child constructs the notions of object, time, space and causality. These notions suggests themselves as likely candidates for primitives of an ontology of commonsense reasoning.

The present research with a number of modest and simple tests has helped to make a first trial of a formal way of describing and talking about commonsense ideas about motion. The results suggest that the model can give some insight into the origins and structure of commonsense conceptions of motion. In so far as this is true, it provides a language for teachers to use in thinking with pupils about the differences between commonsense and Newtonian (or other) theories of motion. There is thus a case for using these ideas in initial and in-service training. More important, however, in the long run may be this initial success, however partial, to describe commonsense ideas clearly enough for the accuracy of the description to be amenable to independent testing.

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APPENDIX I

COMICSTRIPS USED FOR INTERVIEW STUDY

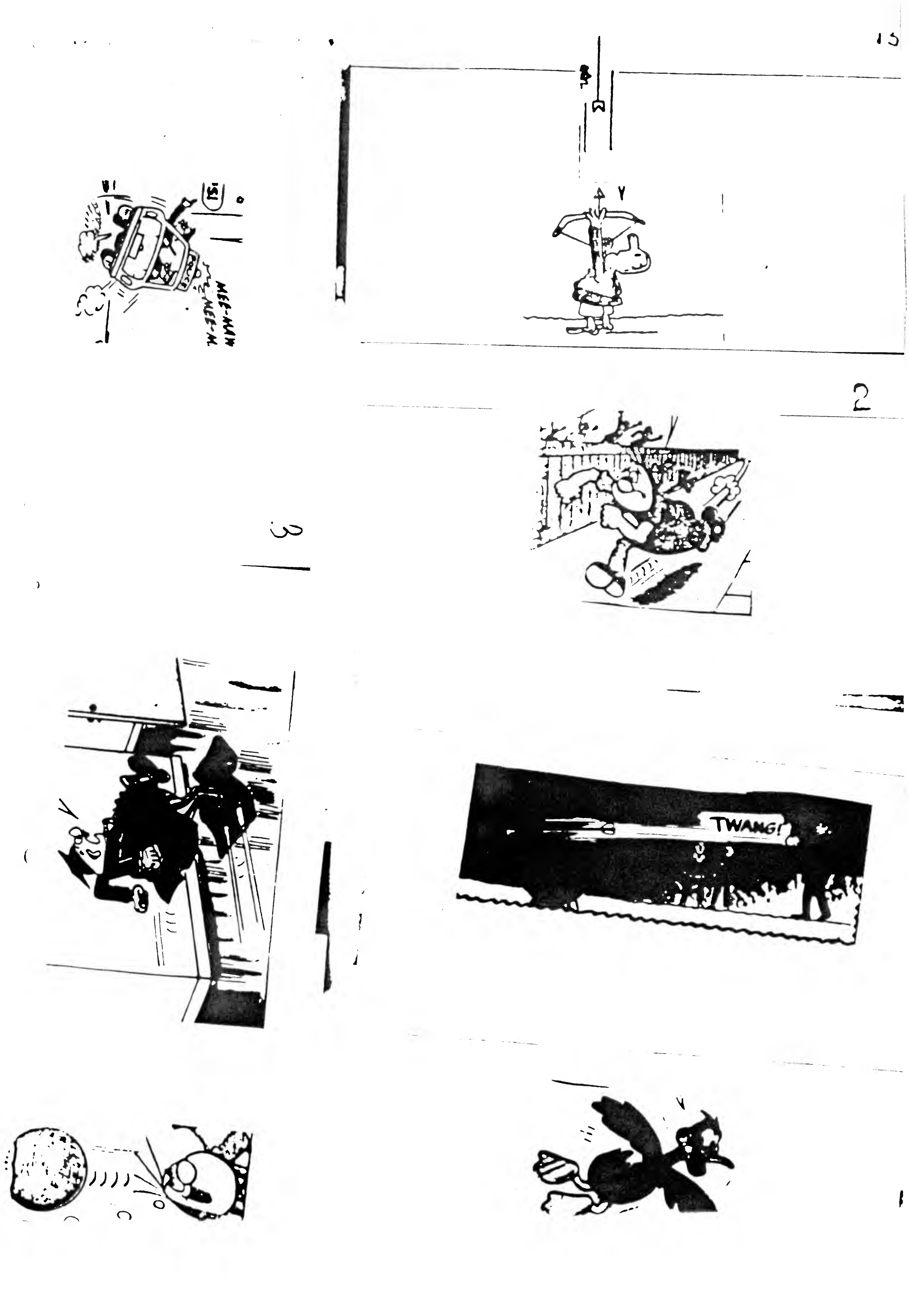
(SEE CHAPTER 5)

PAGES 291-296 REDACTED DUE TO THIRD PARTY RIGHTS OR OTHER LEGAL ISSUES

APPENDIX II

PICTURES USED IN REPERTORY GRID STUDY

(SEE CHAPTER 5)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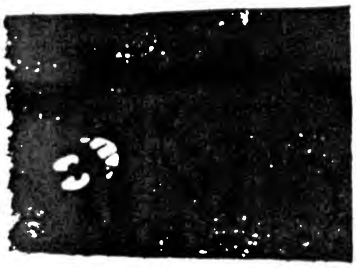

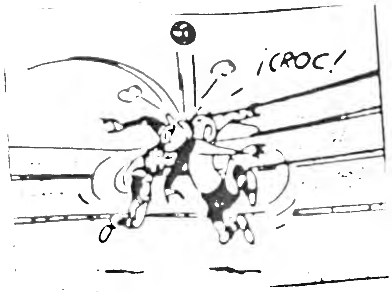
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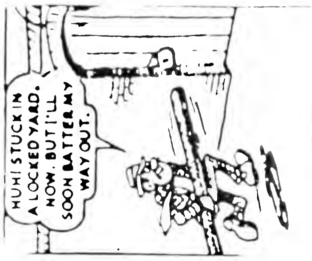
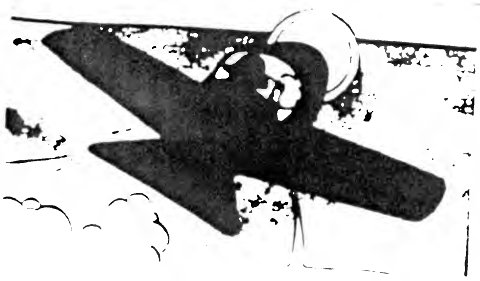

HUH! STUCK IN A LOCKED YARD. NOW, BUT I'LL SOON BATTER MY WAY OUT.



APPENDIX III

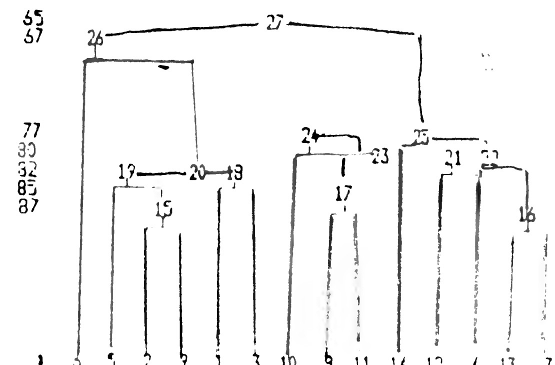
FOCUSED GRIDS FROM REPERTORY GRID STUDY

(SEE CHAPTER 5)

FOCUSed Repertory Grid

Name of Subject: 6th Year | **Number of Grid: 1**

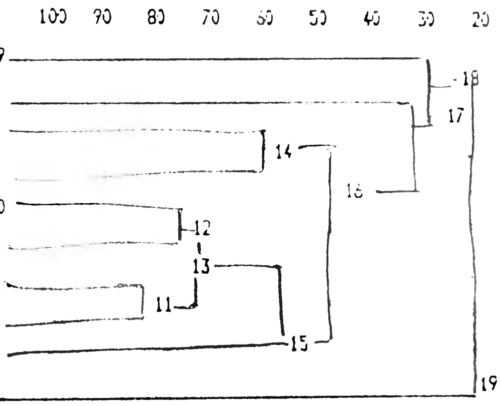
FOCUSED GRID 1



ELEMENTS

E14 DRAINPIPE SNAPS
E13 ARROW ACROSS
E12 BERYL-BALL ON HEAD
E11 ARROW UP
E10 BIRD
E9 FRED-BATTERING RAM
E8 AEROPLANE
E7 KITE
E6 SLIDING
E5 BRYL POGOSTICK
E4 FOOTBALLERS
E3 POLICECAR
E2 BERYL RUNNING
E1 BOWLS

	6	5	2	9	1	3	10	8	11	14	12	4	13	7	
9	1	5	2	2	2	1	2	1	1	4	5	5	5	5	9
8	5	5	4	4	4	4	1	1	4	5	5	5	5	1	8
1	1	5	5	5	5	5	5	5	5	5	5	5	1	1	1
2	1	5	5	5	5	5	1	5	5	5	5	5	5	5	2
10	1	1	1	5	5	5	5	5	5	1	5	5	5	5	10
6	1	1	1	1	5	5	5	5	5	5	5	5	5	5	6
5	1	1	1	1	1	1	5	5	5	5	5	5	5	5	5
3	1	1	1	1	1	1	1	4	5	5	4	5	5	5	3
7	1	2	2	1	1	5	5	5	5	5	2	5	5	5	7
4	4	4	1	1	4	2	4	3	5	5	5	1	5	4	4



Constructs

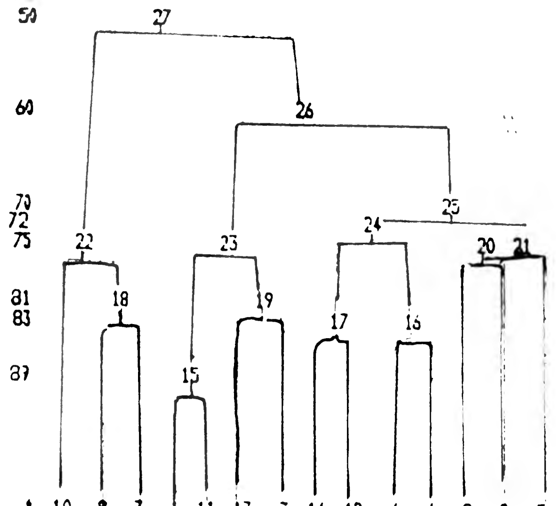
1. Need fuel to move – doesn't need fuel to move
2. Needs manpower to start it – doesn't need a man to start it
3. Not wind assisted – wind assisted
4. Projectile moves through air – doesn't move through air
5. Ground assisted – air assisted
6. Shape helps move faster – shape doesn't help move faster
7. Friction stops motion – Friction not stopping motion
8. Gravity makes things fall – Kept up in spite of gravity
9. Moves across – moves up and down
10. Objects thrown or fired – not thrown or fired

Constructs 3, 5, 7, and 9 reversed

FOCUSed Repertory Grid

Name of Subject: 6th year Science Student Phys. Chem. Maths

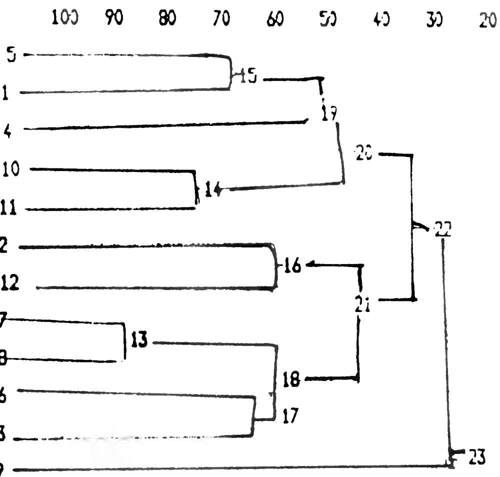
Number of Grid: 2



ELEMENTS

E14 DRAINPIPE SNAPS
E13 ARROW ACROSS
E12 BERYL-BALL ON HEAD
E11 ARROW UP
E10 BIRD
E9 FRED-BATTERING RAM
E8 AEROPLANE
E7 KITE
E6 SLIDING
E5 BRYL POGOSTICK
E4 FOOTBALLERS
E3 POLICECAR
E2 BERYL RUNNING
E1 BOWLS

	10	8	3	1	11	13	7	14	12	4	6	2	9	5	
5	5	1	1	1	1	1	1	5	5	5	5	1	1	1	5
1	1	1	2	2	1	1	2	5	5	5	4	2	2	1	1
4	1	1	1	1	1	1	1	5	5	5	5	5	5	5	4
10	5	1	5	1	1	5	5	5	5	5	5	5	5	5	10
11	5	1	1	1	1	5	5	1	5	5	5	5	5	5	11
2	1	1	1	5	5	5	1	1-	5	1	5	5	5	5	2
12	1	1	1	5	5	5	1	5	5	5	5	1	5	5	12
7	1	1	1	5	5	5	5	5	5	5	5	5	1	1	7
8	1	1	1	5	5	5	5	5	5	5	5	1	1	1	8
6	1	1	1	5	5	5	5	5	5	1	1	1	1	5	6
3	1	1	1	1	1	5	5	5	5	4	1	1	1	4	3
9	5	5	1	1	5	5	5	5	5	1	1	1	5	1	9



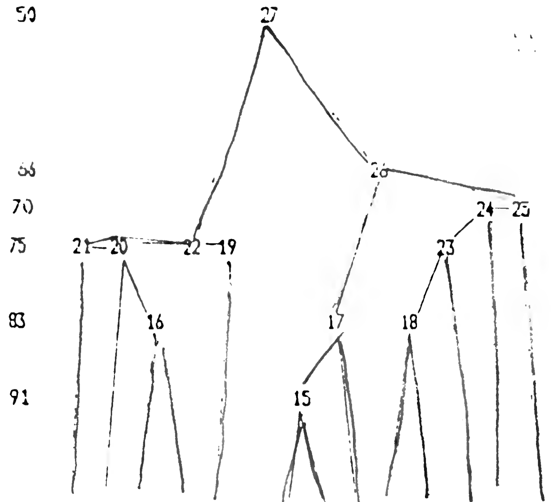
1. Powered flight - falling through air
2. Man working force - not man made
3. Movement parallel to earth - movement not parallel to earth
4. Movement to move a man - movement not made to move a man
5. Accidental movement - deliberate movement
6. Potential Energy change - chemical change causing movement
7. Controlled movement - not controlled movement
8. Movement for a purpose - movement not for a purpose
9. Movement on earth - movement not on earth
10. **Fast** - **slow**
11. **Not much movement** - **moves a lot, a big movement**
12. **Movement causes damage** - **movement does not cause damage**

Constructs 1, 3, 7, 8, and 9 reversed

FOCUSed Reperty Grid

Name of Subject: 6th Form "A" Level Arts Student | **Number of Grid:** 3

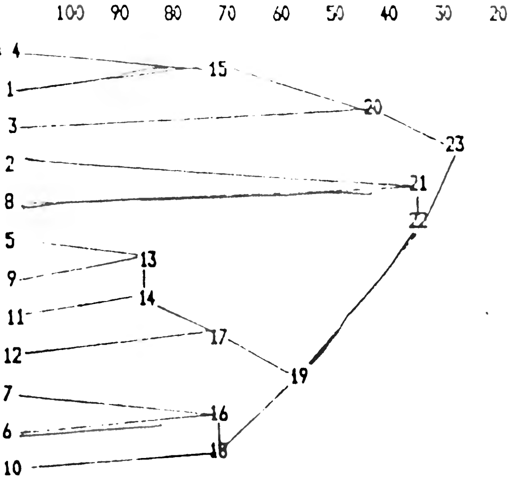
FOCUSED GRID 3



ELEMENTS

E14 DRAINPIPE SNAPS
E13 ARROW ACROSS
E12 BERYL-BALL ON HEAD
E11 ARROW UP
E10 BIRD
E9 FRED-BATTERING RAM
E8 AEROPLANE
E7 KITE
E6 SLIDING
E5 BRYL POGOSTICK
E4 FOOTBALLERS
E3 POLICECAR
E2 BERYL RUNNING
E1 BOWLS

Construct	3	6	2	9	5	1	8	7	10	11	13	4	14	12	Construct
4	1	5	5	5	5	5	1	1	1	5	5	5	5	5	4
1	1	5	5	5	5	1	1	1	1	5	5	5	5	1	1
3	1	5	1	5	5	1	1	5	5	5	5	5	5	5	3
2	5	5	1	1	5	5	5	5	1	5	5	5	5	5	2
8	1	1	1	1	5	1	5	5	1	1	5	5	3	5	8
5	1	1	1	1	1	1	5	5	5	5	5	1	5	5	5
9	1	1	1	1	1	1	5	5	5	5	5	5	5	5	9
11	1	1	1	1	1	1	5	5	5	1	5	5	5	5	11
12	1	1	1	1	1	1	5	5	5	5	5	5	1	5	12
7	1	1	1	1	5	5	5	5	5	5	5	5	1	1	7
6	1	1	1	5	5	5	5	5	5	5	5	1	1	1	6
10	1	1	5	5	5	5	5	5	5	5	5	1	1	5	10



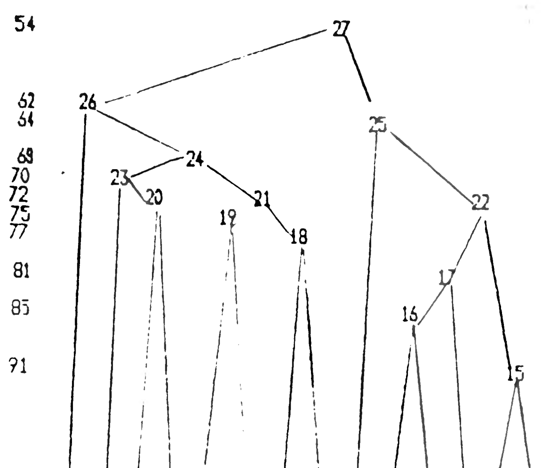
Constructs

1. Humans move on own – humans powered by engine
2. Moving on own – not moving on own
3. Moving needs another force apart from own attributes – moving doesn't need another force
4. Need force gravity to move – doesn't need gravity to move
5. Friction stops movement – no friction
6. Shape helps movement – shape doesn't help movement
7. Light move easily – heavy no move so easily
8. Upward direction of movement – horizontal direction of movement
9. Things move along on ground – things not on ground
10. Falling over losing balance – not falling maintaining balance
11. Moving in air – not moving in air

FOCUSed Repertory Grid

Name of Subject: 1st year | Number of Grid: 5

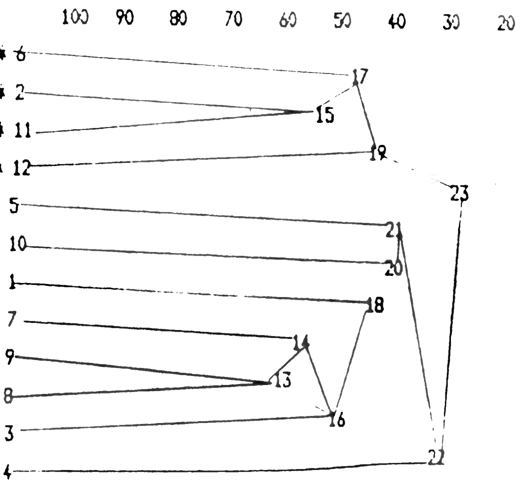
FOCUSED GRID 5



ELEMENTS

E14 DRAINPIPE SNAPS
E13 ARROW ACROSS
E12 BERYL-BALL ON HEAD
E11 ARROW UP
E10 BIRD
E9 FRED-BATTERING RAM
E8 AEROPLANE
E7 KITE
E6 SLIDING
E5 BRYL POGOSTICK
E4 FOOTBALLERS
E3 POLICECAR
E2 BERYL RUNNING
E1 BOWLS

	14	6	4	7	13	11	8	10	3	9	2	1	12	5	
6	1	1	1	1	1	1	5	1	5	1	1	1	1	1	6
2	4	1	1	1	5	5	5	4	5	1	2	1	1	1	2
11	1	1	1	5	5	5	5	5	1	1	1	1	1	1	11
12	5	2	1	5	5	5	2	3	2	5	2	1	1	1	12
5	5	4	2	4	1	1	2	3	5	5	3	1	1	5	5
10	1	5	5	4	1	1	1	1	5	5	4	2	2	2	10
1	2	5	1	1	1	1	1	1	2	5	5	5	1	1	1
7	2	5	2	1	1	5	5	5	5	5	5	5	1	1	7
9	1	1	1	1	1	5	5	5	5	5	5	5	4	4	9
8	1	1	1	2	5	1	5	5	5	5	5	5	5	5	8
3	1	1	4	4	5	5	5	1	4	5	5	5	5	5	3
4	2	3	4	4	3	3	4	4	2	4	4	1	5	5	4



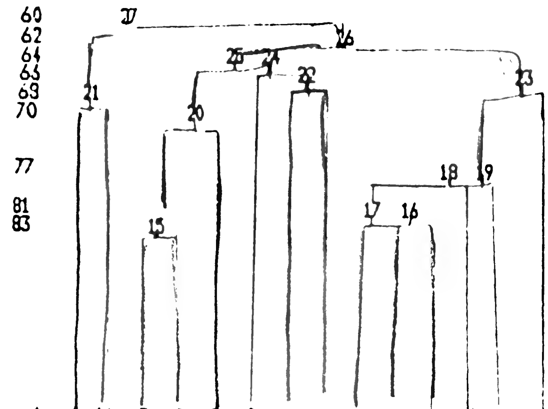
Constructs

1.	Movement through air	- movement on ground
2.	Fast	- slow
3.	Moved by person/person in control	- person not in control
4.	Bouncing	- rolling
5.	Moving and holding object	- person standing still and not holding object
6.	Moving in something	- not moving in something
7.	Moving across	- moving up
8.	Deliberate action	- accidental
9.	Moving for a purpose	- not moving for a purpose
10.	Shape increases speed of movement	- shape decreases speed of movement
11.	Gravity helps motion	- gravity does not help motion
12.	Somebody pulling to cause motion	- somebody pushing to cause motion

FOCUSed Repertory Grid

Name of Subject: 1st year **Number of Grid:6**

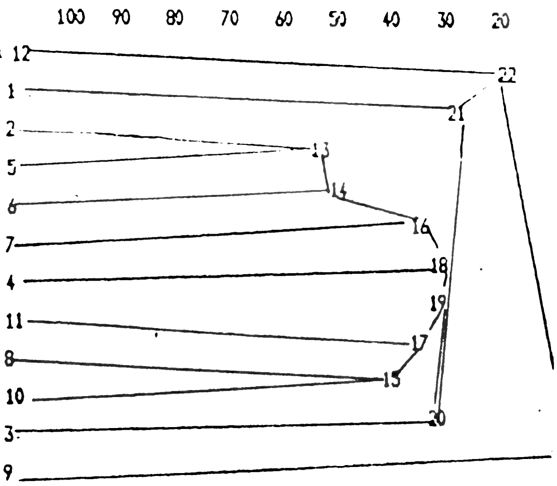
FOCUSED GRID 6



ELEMENTS

E14 DRAINPIPE SNAPS
E13 ARROW ACROSS
E12 BERYL-BALL ON HEAD
E11 ARROW UP
E10 BIRD
E9 FRED-BATTERING RAM
E8 AEROPLANE
E7 KITE
E6 SLIDING
E5 BRYL POGOSTICK
E4 FOOTBALLERS
E3 POLICECAR
E2 BERYL RUNNING
E1 BOWLS

Construct	6	14	3	8	7	9	2	10	11	13	1	5	12	4	Construct
12	5	5	1	1	1	5	1	5	5	5	5	5	5	5	12
1	5	5	5	5	1	1	2	2	2	5	5	5	5	1	1
2	2	2	5	5	3	1	1	3	5	5	5	2	5	5	2
5	3	1	5	5	5	1	1	1	5	5	5	5	5	1	5
6	1	5	5	5	5	5	1	1	5	5	5	5	1	1	6
7	1	1	5	5	4	4	2	5	4	4	4	4	4	1	7
4	3	1	1	3	5	5	5	5	1	5	5	4	5	1	4
11	1	1	1	1	1	5	5	5	5	5	5	1	1	1	11
8	1	1	1	1	3	1	5	5	5	5	5	5	5	5	8
10	5	1	1	2	2	1	2	5	5	5	2	3	4	3	10
3	1	4	1	5	2	2	1	5	2	4	1	2	4	4	3
9	1	1	2	1	1	1	1	1	1	1	4	5	5	5	9



Constructs

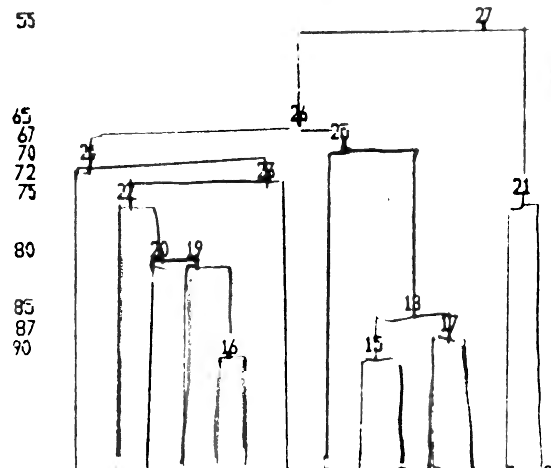
1. Move fast - move slow
2. People running - people standing still
3. Moving on ground - moving in the air
4. Moving to get away - moving towards something
5. Something propelling them - something not propelling them. Moving on own.
6. People holding something and doing something - people not holding something
7. Controlled movement can be changed - non controlled movement cannot be changed
8. Natural - unnatural
9. Bouncing - not bouncing
10. **Held up in air by light material** - **on ground, heavy material**
11. **Muscles to cause movement** - **not muscles but something else causing movement**
12. **Need fuel** - **don't need a fuel**

Constructs 2, 3 and 12 reversed

FOCUSed Repertory Grid

Name of Subject: 1st year **Number of Grid: 7**

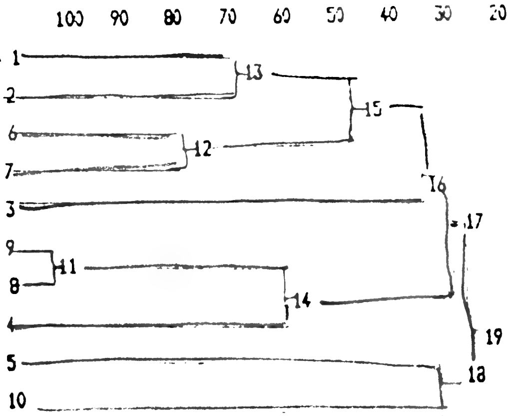
FOCUSED GRID 7



ELEMENTS

E14 DRAINPIPE SNAPS
E13 ARROW ACROSS
E12 BERYL-BALL ON HEAD
E11 ARROW UP
E10 BIRD
E9 FRED-BATTERING RAM
E8 AEROPLANE
E7 KITE
E6 SLIDING
E5 BRYL POGOSTICK
E4 FOOTBALLERS
E3 POLICECAR
E2 BERYL RUNNING
E1 BOWLS

	4	5	9	2	6	14	7	10	11	13	12	1	3	8	
1	1	5	5	1	1	1	1	4	5	5	5	5	5	1	1
2	1	5	5	5	1	1	2	5	5	5	5	5	5	5	2
6	2	4	1	1	2	3	3	3	5	5	5	5	5	5	6
7	1	2	1	1	2	3	5	1	5	5	5	5	5	5	7
3	1	2	1	1	1	3	4	5	4	4	2	1	1	5	3
9	1	1	1	1	1	1	1	1	1	1	1	1	5	5	9
8	1	1	1	1	1	1	1	1	1	1	1	1	5	5	8
4	5	5	5	1	1	1	1	1	1	1	1	1	5	5	4
5	5	5	3	3	1	1	5	5	1	5	5	1	3	5	5
10	5	5	2	2	2	2	5	2	1	1	5	5	1	1	10



Constructs

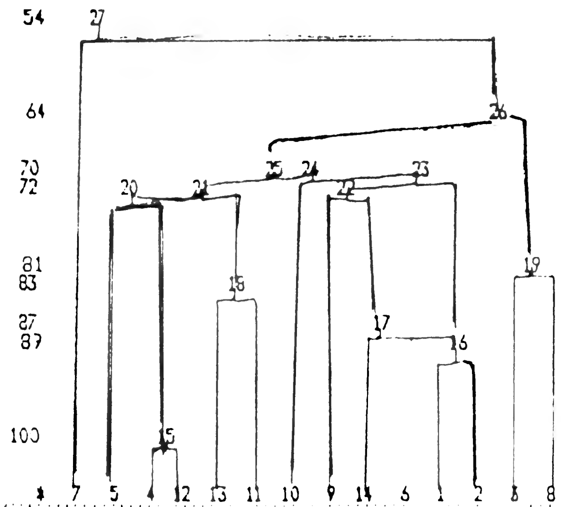
1. Something to help it move – moving on its own
2. Accidental – deliberate movement
3. Flying – movement on the ground
4. Moving towards – moving away
5. Moving up – moving down
6. People running – people still
7. People moving – objects moving
8. Moving in something – not moving in something
9. Movement with engine – movement without engine
10. Fast – slow

Constructs 2, 6, 7, and 10 reversed

FOCUSed Repertory Grid

Name of Subject: 6th year Science Student Phys. Chem. Maths **Number of Grid:** 8

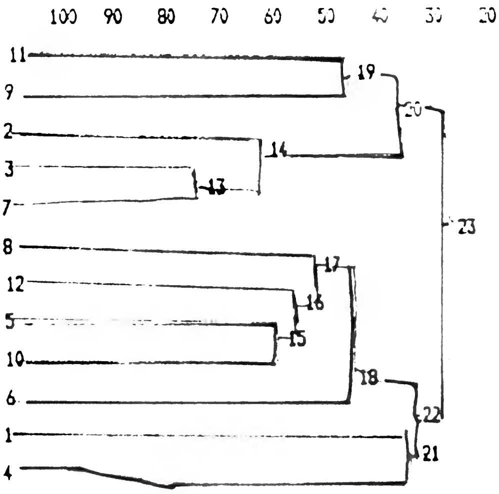
FOCUSED GRID 8



ELEMENTS

E14 DRAINPIPE SNAPS
E13 ARROW ACROSS
E12 BERYL-BALL ON HEAD
E11 ARROW UP
E10 BIRD
E9 FRED-BATTERING RAM
E8 AEROPLANE
E7 KITE
E6 SLIDING
E5 BRYL POGOSTICK
E4 FOOTBALLERS
E3 POLICECAR
E2 BERYL RUNNING
E1 BOWLS

	7	5	4	12	13	11	10	9	14	6	1	2	8	8	
11	1	1	5	5	1	1	1	1	1	4	5	5	5	4	11
9	4	1	1	1	1	1	1	1	1	2	5	5	5	1	9
2	5	1	1	1	1	1	5	1	1	1	1	1	5	5	2
3	1	2	1	1	2	2	1	1	1	1	1	1	5	5	3
7	1	1	1	1	4	4	4	1	1	1	1	1	5	5	7
8	1	5	4	4	5	5	5	5	1	1	1	5	5	5	8
12	1	1	1	1	5	5	5	5	1	1	5	5	5	5	12
5	4	3	1	1	1	5	4	5	1	3	5	5	5	4	5
10	5	1	1	1	1	5	5	4	5	5	5	5	5	5	10
6	1	2	2	2	2	2	1	5	5	5	5	5	5	5	6
1	1	5	1	1	1	1	4	3	3	3	3	4	5	5	1
4	2	2	1	1	1	1	5	5	5	5	1	1	5	2	4



Constructs

1. **Means transport** – not means transport
2. **People doing something to object to make it move** – moving on its own
3. **Machine provides movement** – no machine for movement
4. **Sport type movement** – non sport type movement
5. **Direction upward/downward** – direction sideways
6. **Stay up off ground defy gravity** – stay on ground don't defy gravity
7. **High speed aerodynamic shape** – not aerodynamic
8. **Needs lot of force** – not lot of force
9. Won't stop dead – stop dead

APPENDIX IV

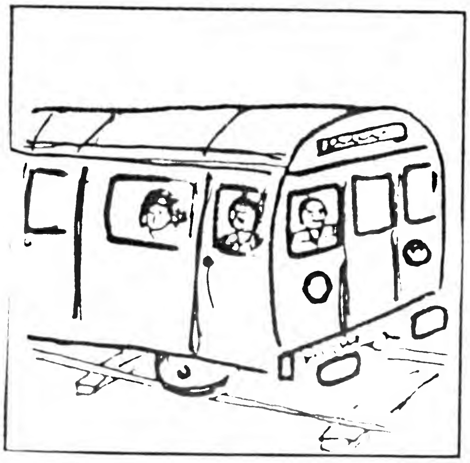
PICTURE EXAMPLES OF STEREOTYPICAL MOTIONS USED IN MATCHING TASK 1-3

APPENDIX IV

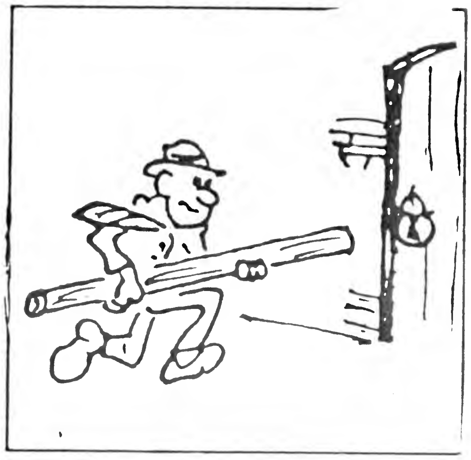
PICTURES TO REPRESENT THE NINE STEREOTYPICAL MOTIONS TESTED IN MATCHING TASK 1

CARRY

The people in the train move



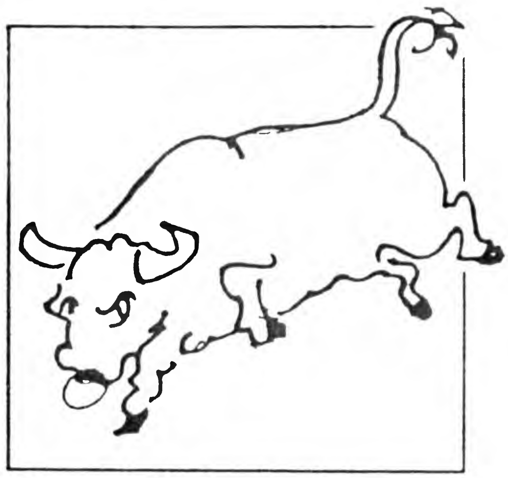
The pole moves



WALK ANIMATE

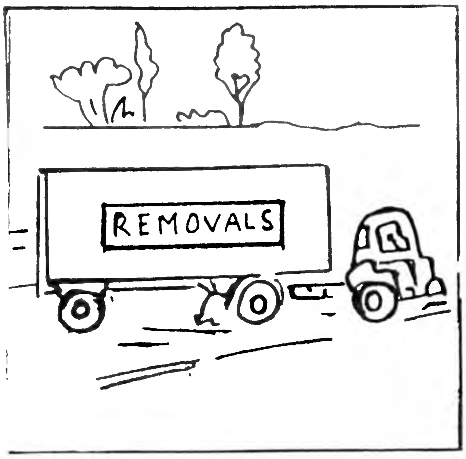
The man moves

The bull moves

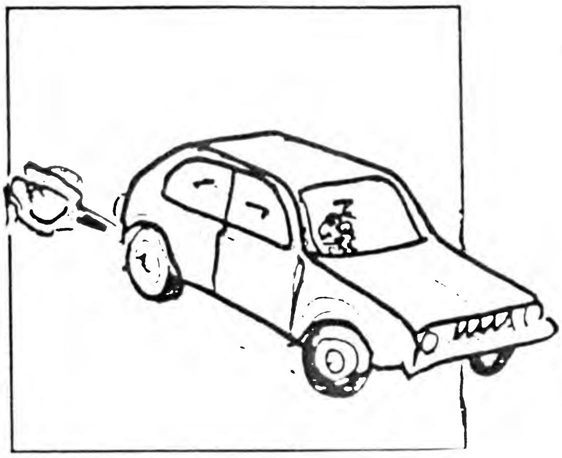


WALK INANIMATE

The lorry moves



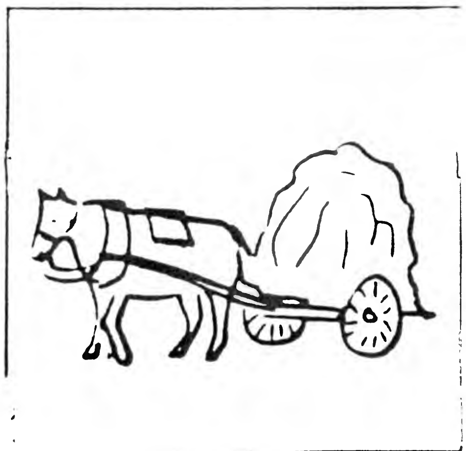
The car moves



PUSH

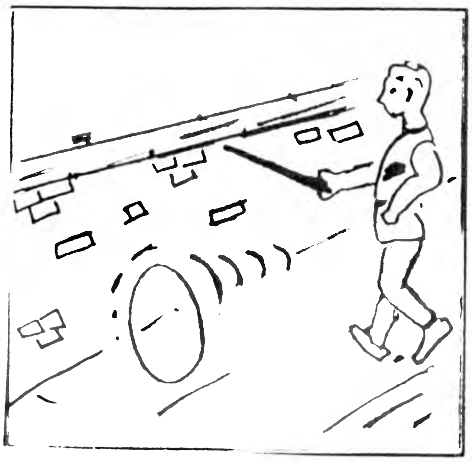
The pram moves

The hay cart moves

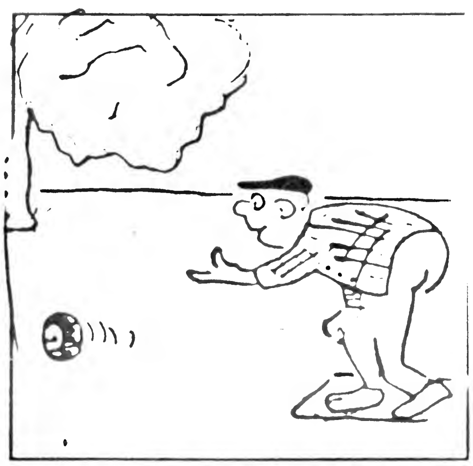


ROLL

The hoop moves

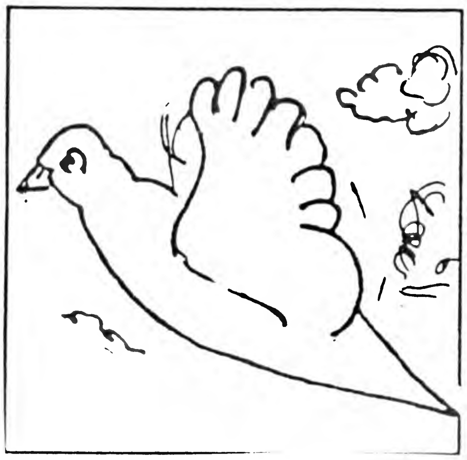


The bowl moves

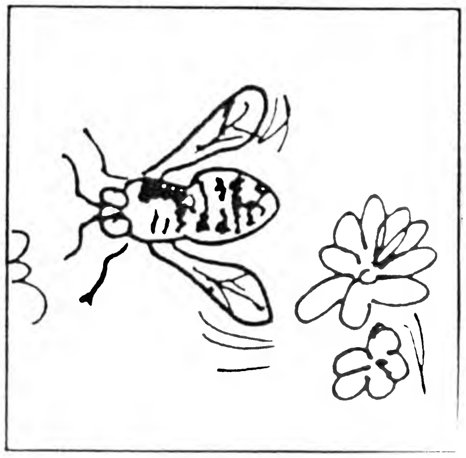


FLY ANIMATE

The bird moves

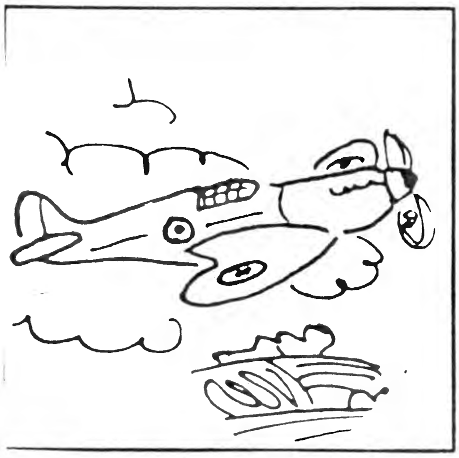


The bee moves

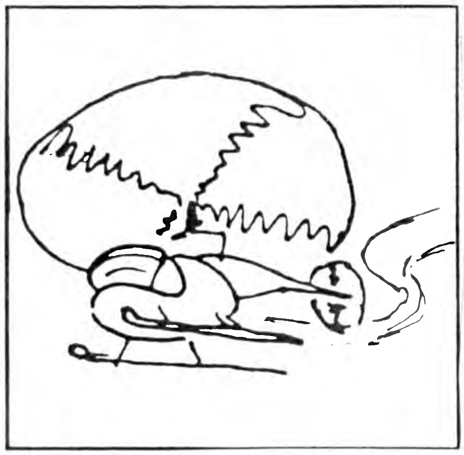


FLY INANIMATE

The plane moves

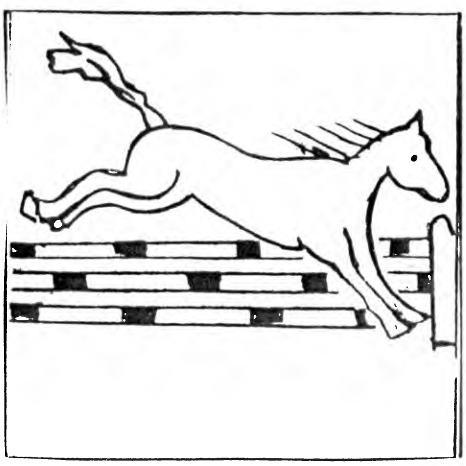


The helicopter moves

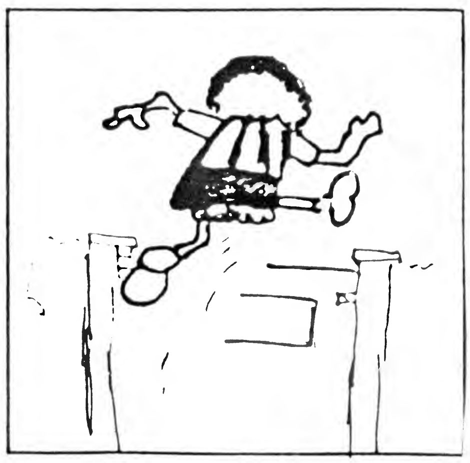


JUMP

The horse moves

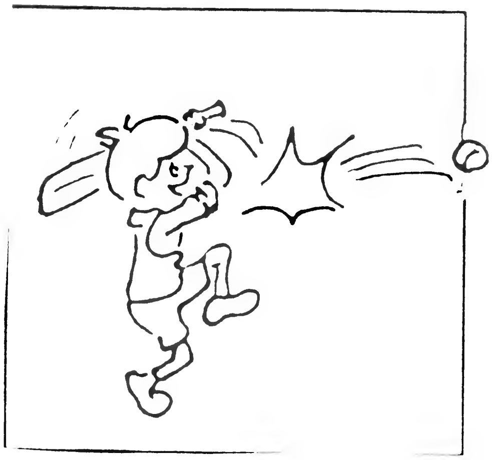


The girls moves

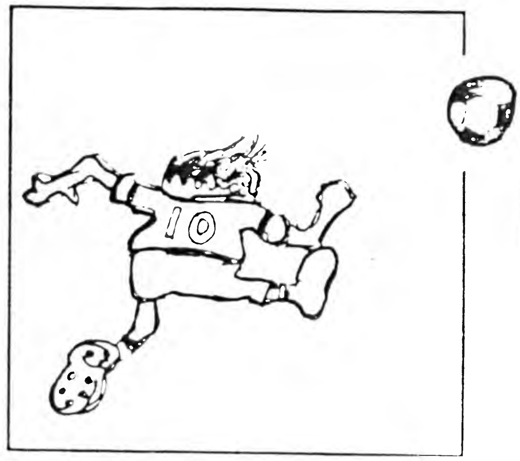


THROW

The ball moves

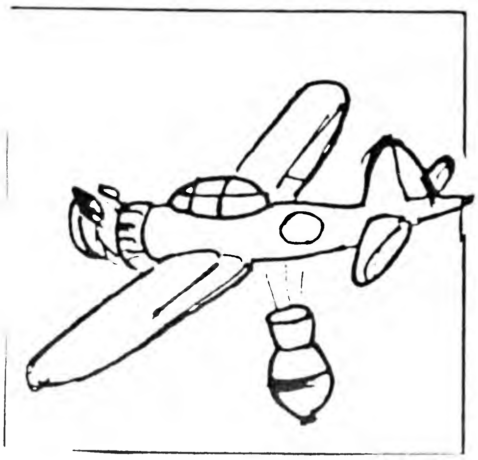


The football moves

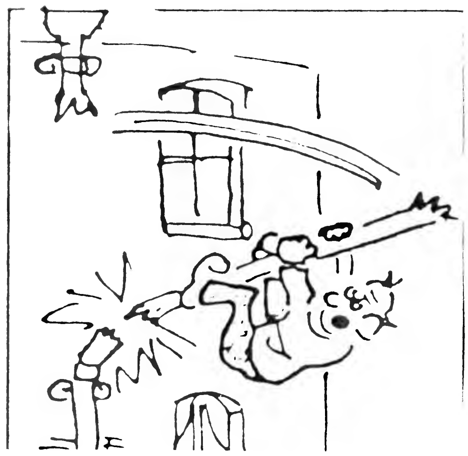


FALL

The bomb moves

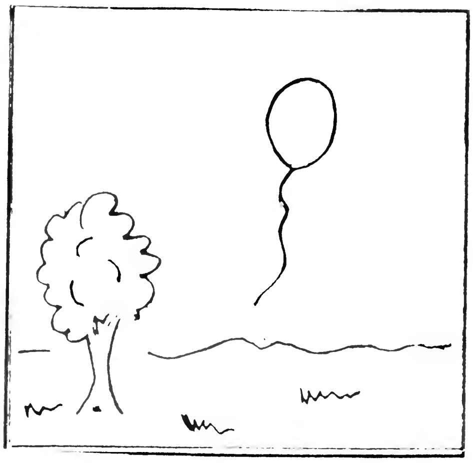


The man moves



FLOAT

The balloon moves



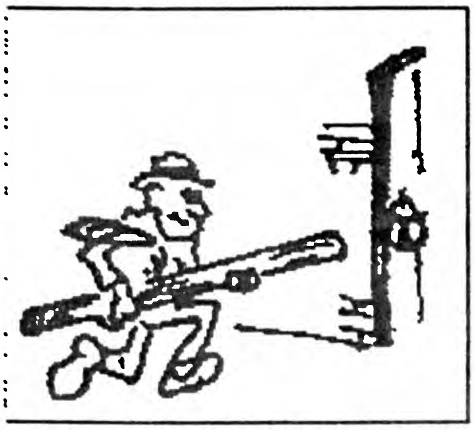
The clouds move

PICTURES TO REPRESENT THE NINE STEREOTYPICAL

MOTIONS TESTED IN MATCHING TASK 2

CARRY ANIMATE PAIR

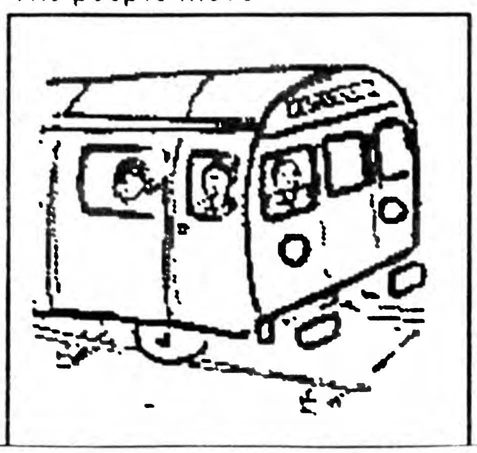
The pole moves



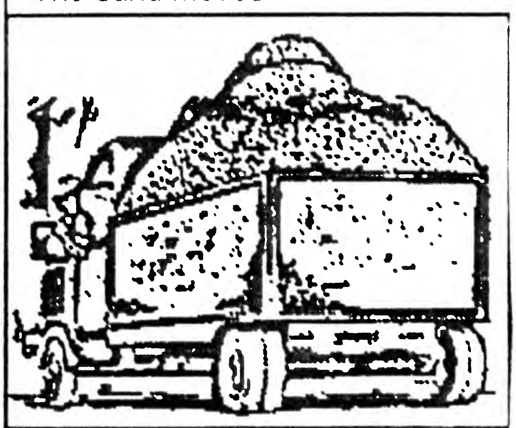
The washing-basket moves

CARRY INANIMATE PAIR

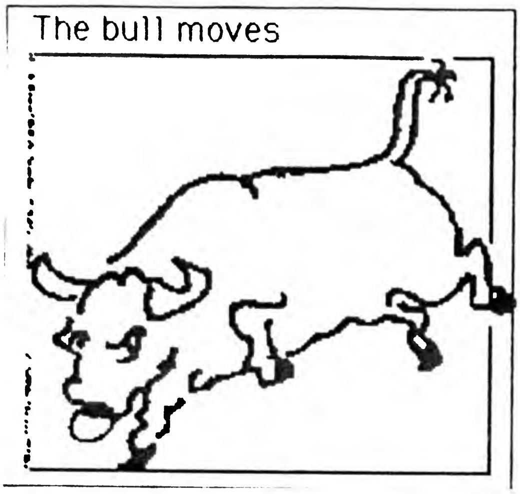
The people move

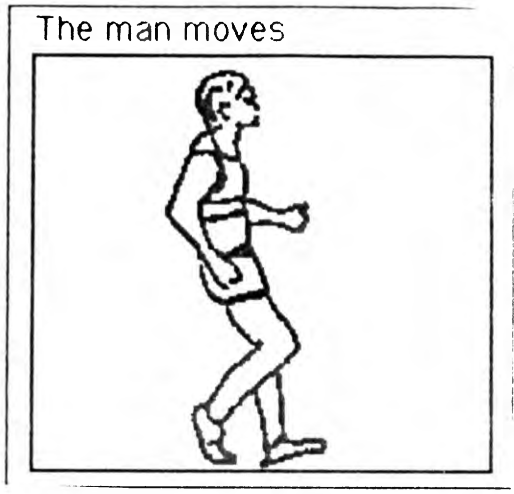


The sand moves

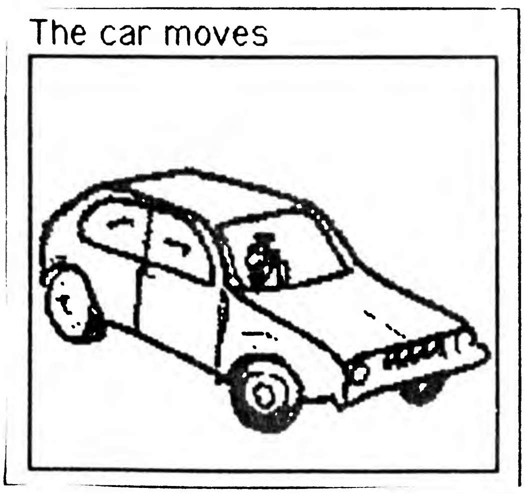


WALK ANIMATE PAIR



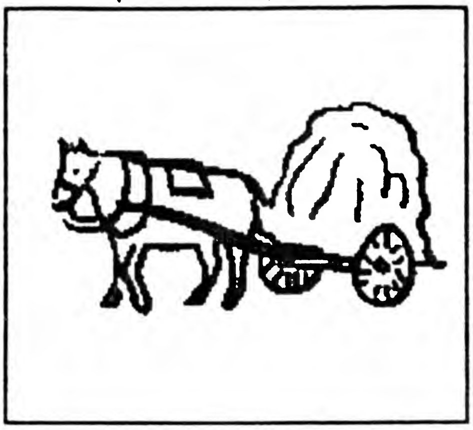


WALK INANIMATE PAIR

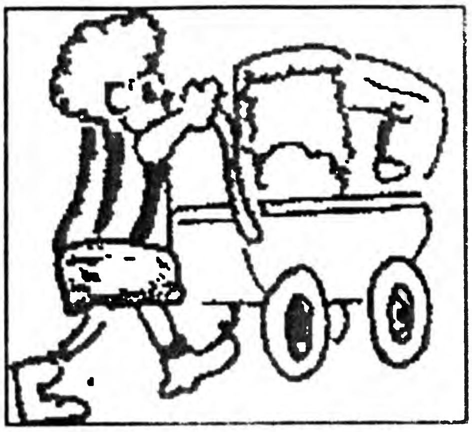


PUSH ANIMATE PAIR

The hay cart moves

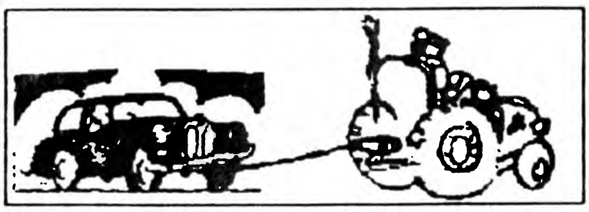


The pram moves

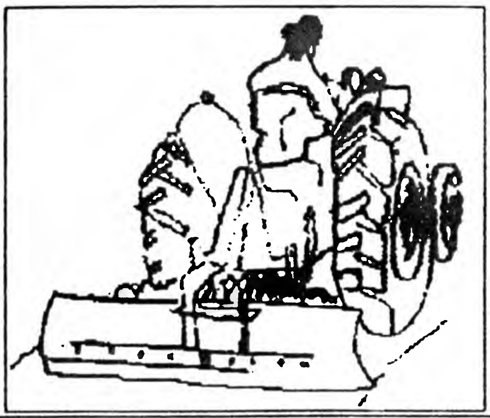


PUSH INANIMATE PAIR

The car moves



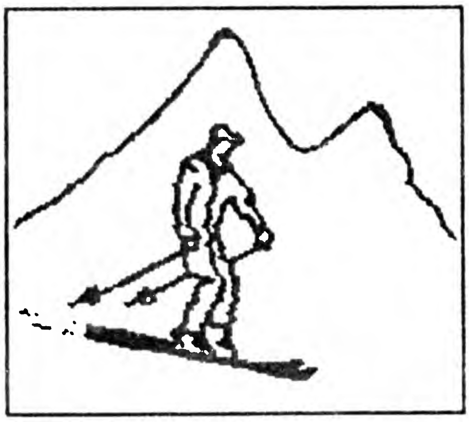
The earth moves



ROLL ANIMATE PAIR

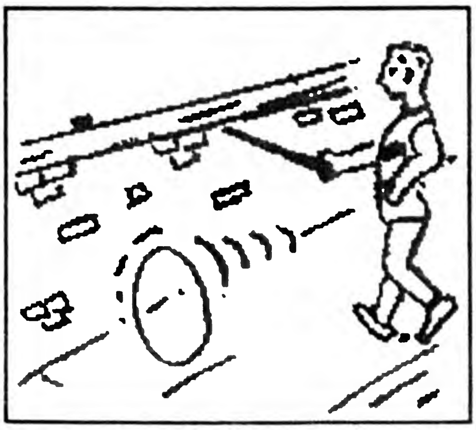
The skater moves

The skier moves

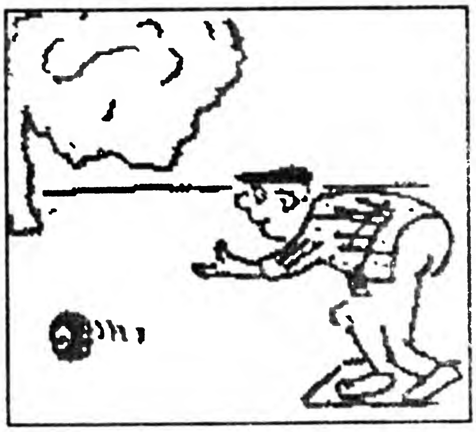


ROLL INANIMATE PAIR

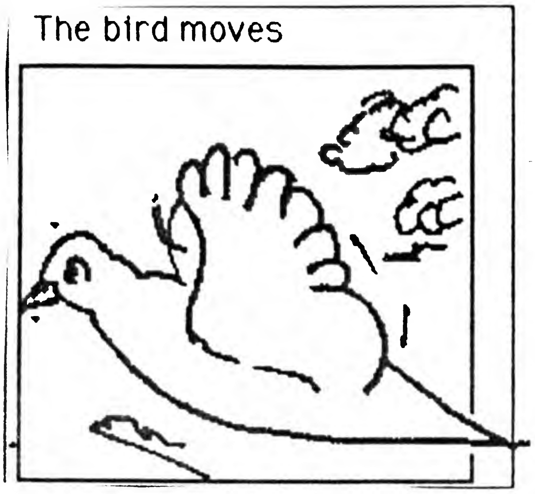
The hoop moves

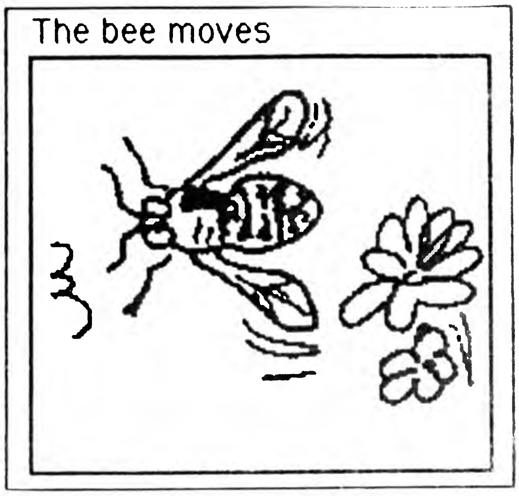


The bowl moves

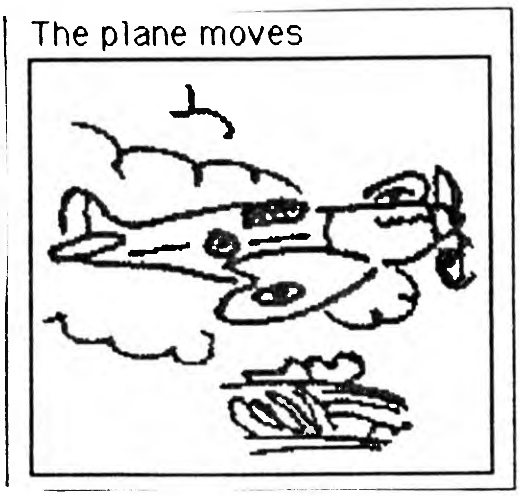


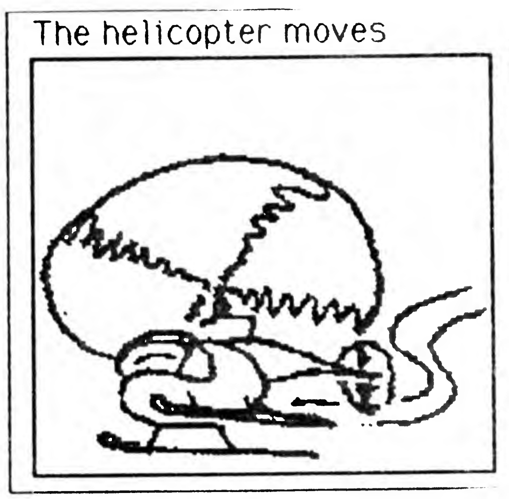
FLY ANIMATE PAIR





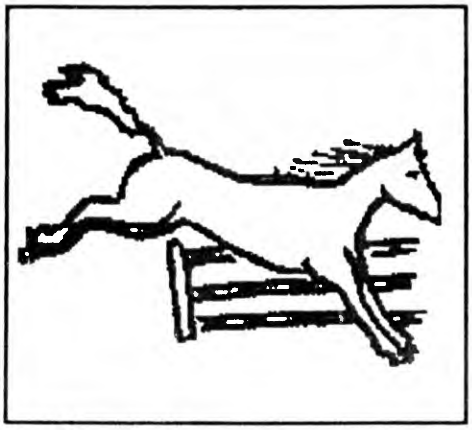
FLY INANIMATE PAIR



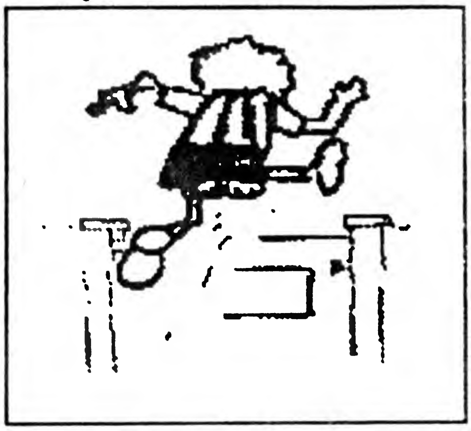


JUMP ANIMATE PAIR

The horse moves

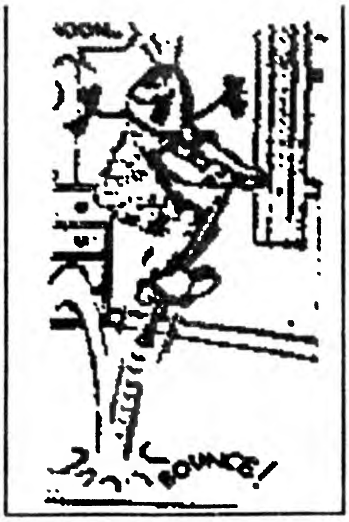


The girl moves

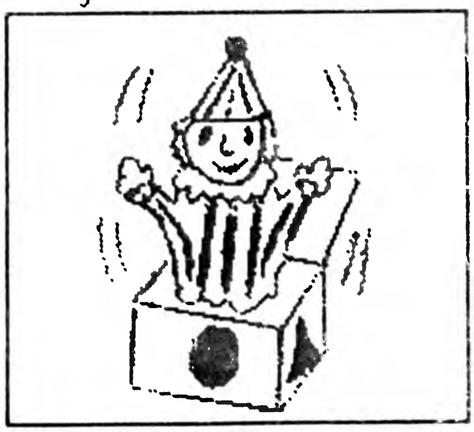


JUMP INANIMATE PAIR

The pogo stick moves

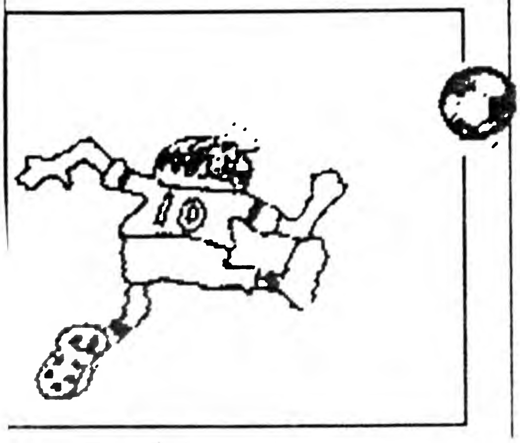


The jackinbox moves



THROW ANIMATE PAIR

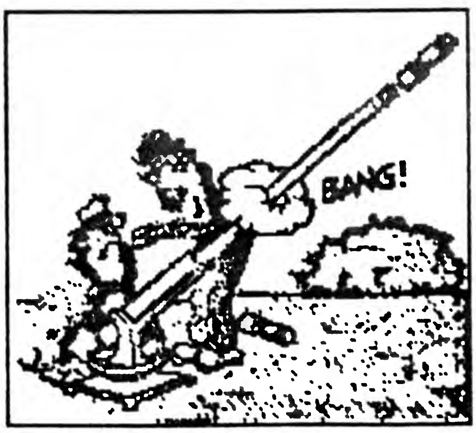
The football moves



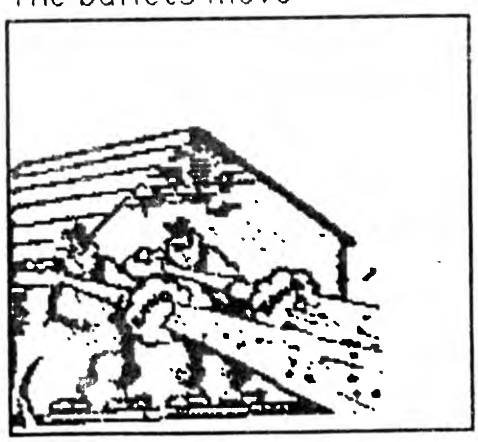
The ball moves

THROW INANIMATE PAIR

The rocket moves

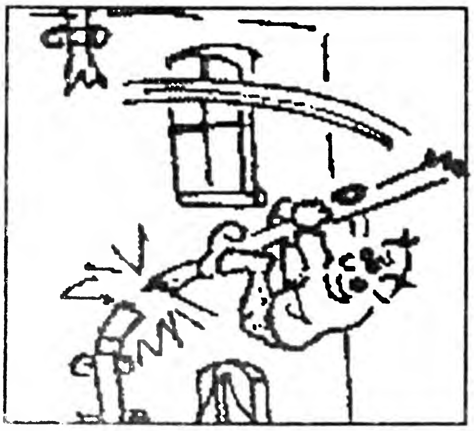


The bullets move



FALL ANIMATE PAIR

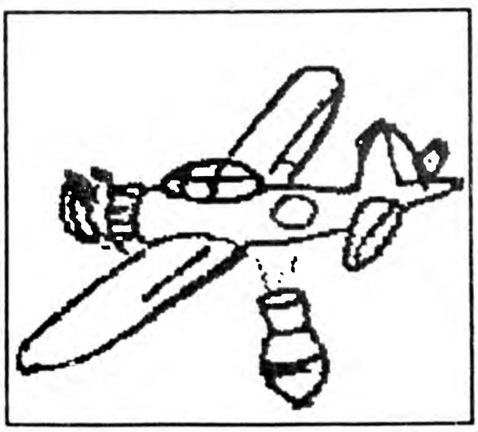
The man moves



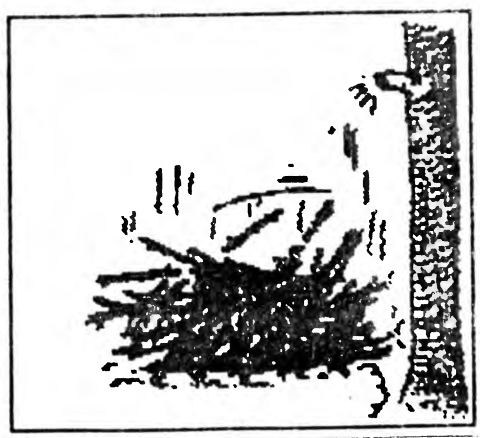
The girl moves

FALL INANIMATE PAIR

The bomb moves

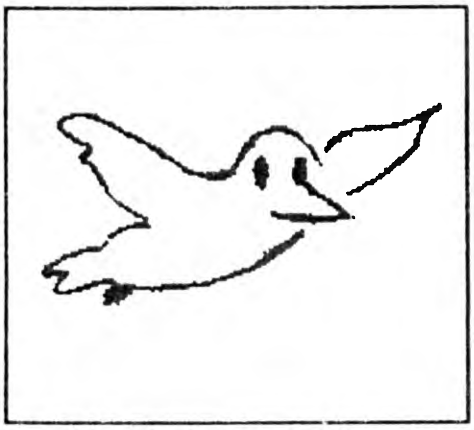


The nest moves

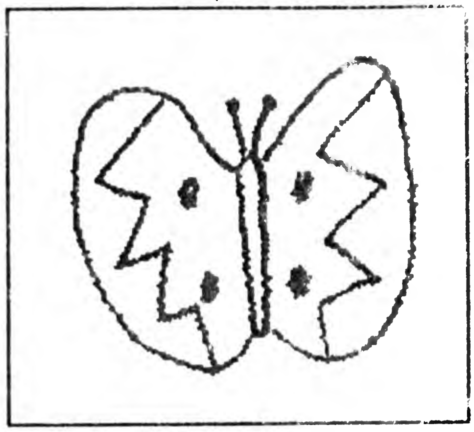


FLOAT ANIMATE PAIR

The bird moves

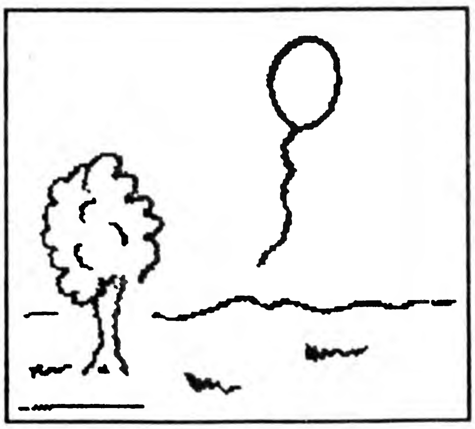


The butterfly moves

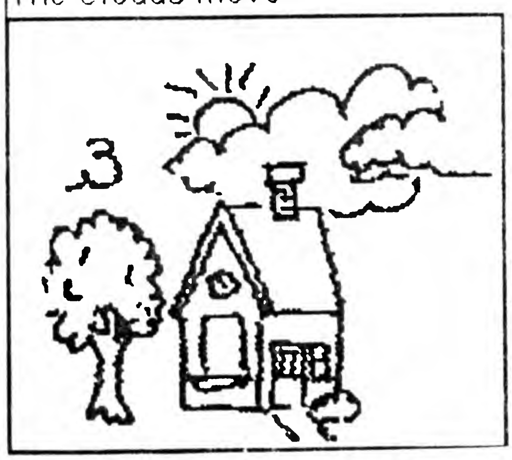


FLOAT INANIMATE PAIR

The balloon moves



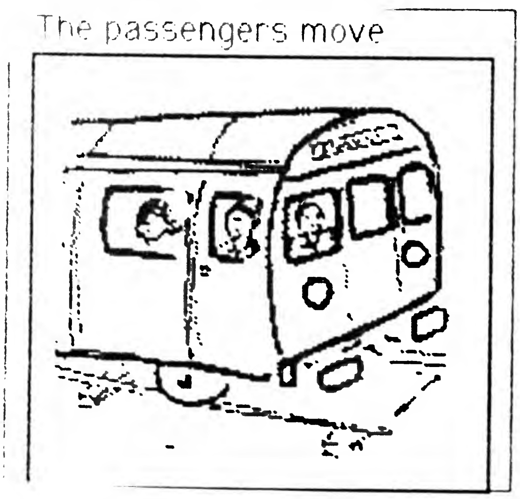
The clouds move

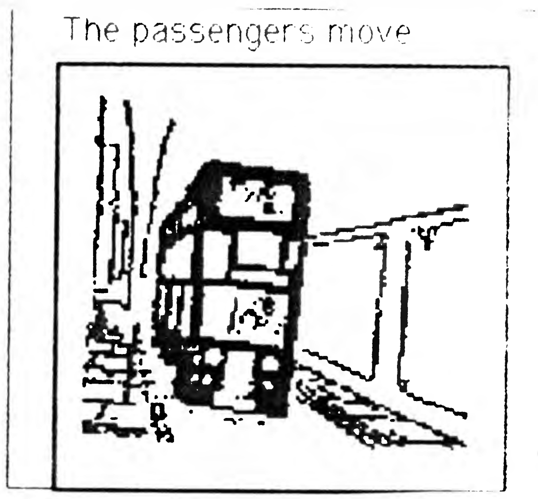


PICTURES USED TO REPRESENT THE NINE STEREOTYPICAL

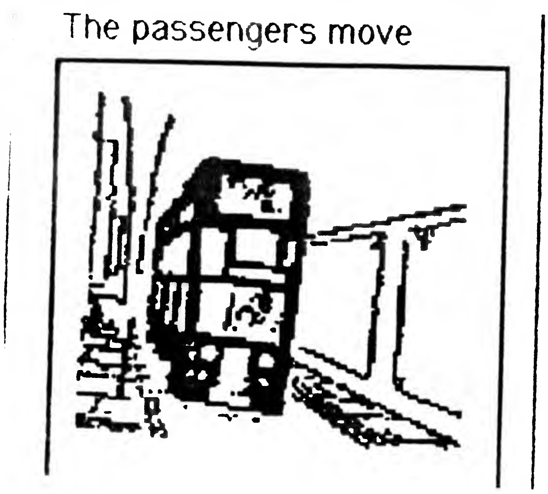
MOTIONS TESTED IN MATCHING TASK 3

CARRY WALK

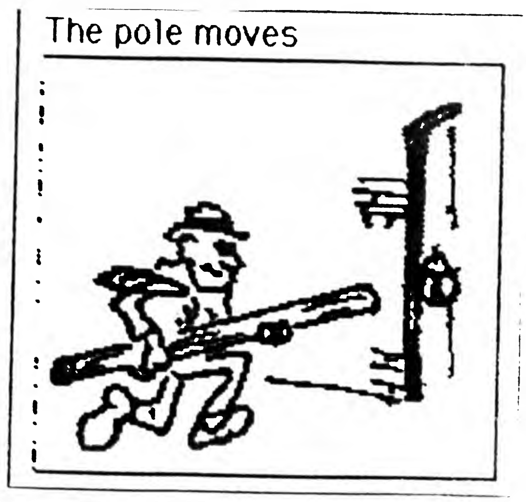




CARRY WALK HELD

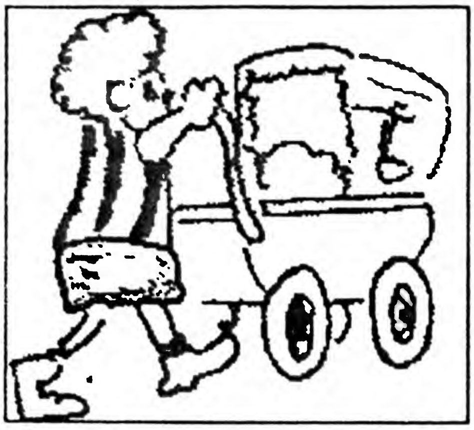


CARRY WALK IN

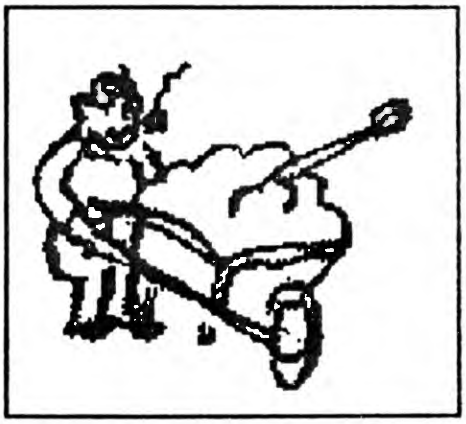


CARRY PUSH

The baby moves

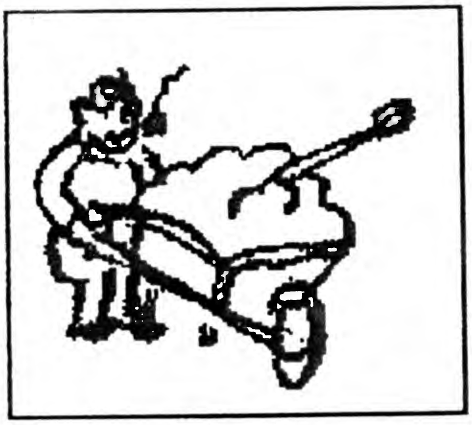


The earth moves



CARRY PUSH IN

The earth moves

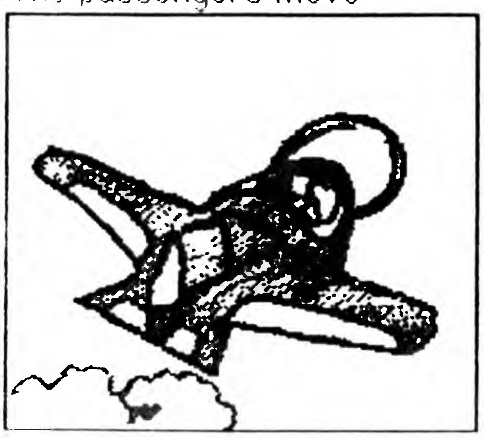


CARRY PUSH HELD

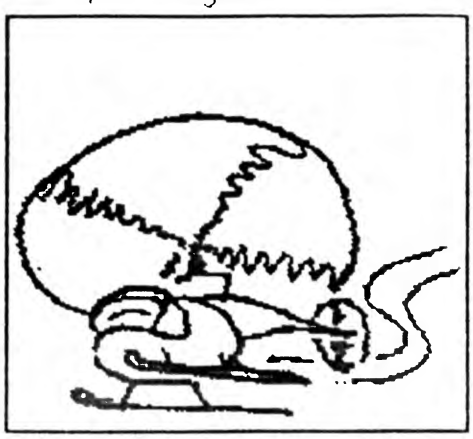
The baby's rattle moves

CARRY FLY

The passengers move

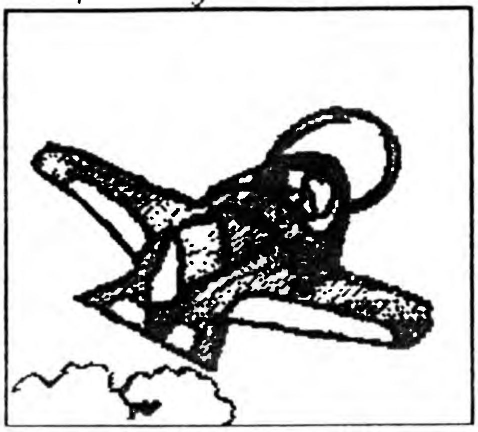


The passengers move



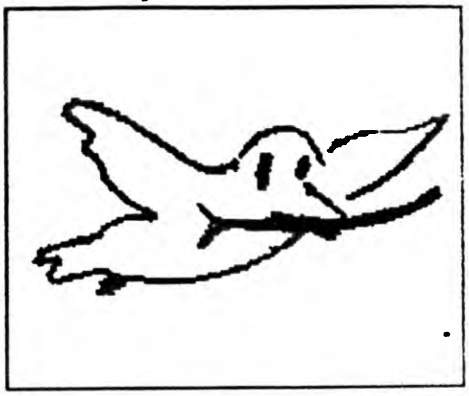
CARRY FLY HELD

The passengers move



CARRY FLY IN

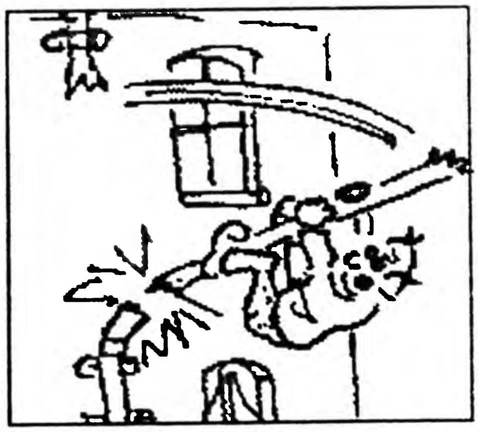
The twig moves



CARRY FALL

The washing moves

The man moves

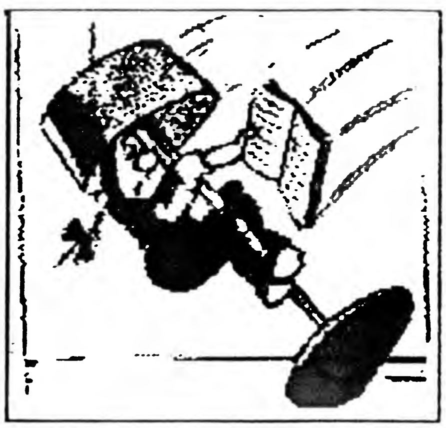


CARRY FALL HELD

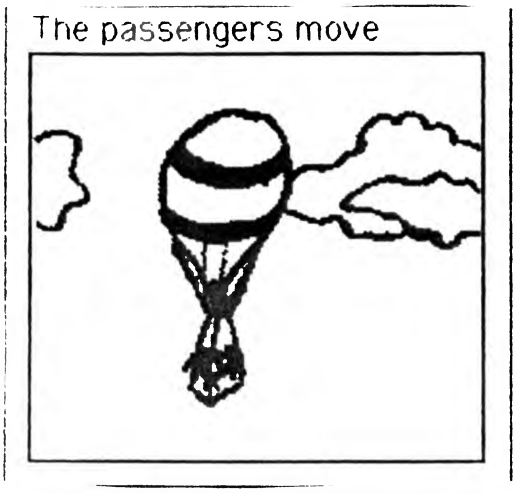
The washing moves

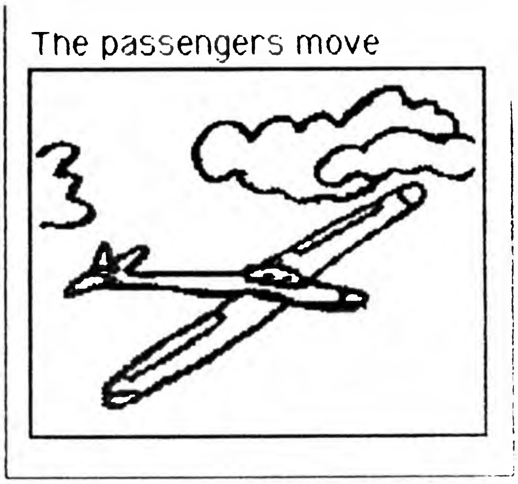
CARRY FALL IN

The book moves

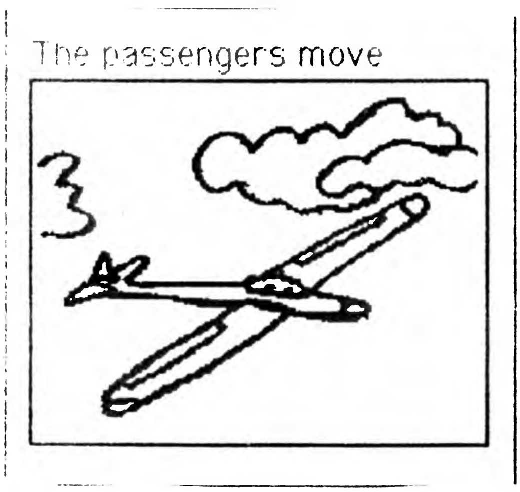


CARRY FLOAT

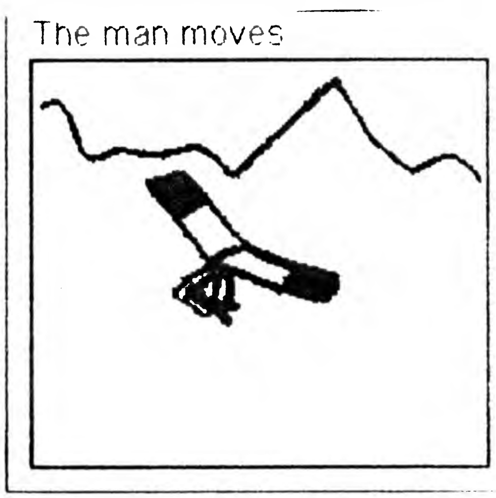




CARRY FLOAT HELD



CARRY FLOAT N



APPENDIX V

ORDER OF EXAMPLES IN MATCHING TASK BOOKLETS

(SEE CHAPTER 8, 9 AND 10)

Table V.1: Randomly ordered examples for Matching Task 1

Example Number	Example Name	Pictures representing classes of motion for comparison.	
1	PUSH THROW (Training example)	Go-cart	Tin can
2	PUSH JUMP	Hay cart	Horse jumping down
3	CARRY ROLL	Carried pole	Bowl
4	FALL CARRY	Man and broken drainpipe	People in train
5	FLY2 FLY2	Aeroplane	Helicopter
6	ROLL FALL	Hoop	Bomb
7	PUSH FLY1	Pram	Bird
8	WALK2 FALL	Car	Man and broken drainpipe
9	JUMP FLY2	Girl	Helicopter
10	CARRY PUSH	Carried pole	Hay cart
11	FLOAT FLOAT	Balloon	Clouds
12	WALK1 CARRY	Man	People in train
13	ROLL THROW	Bowl	Football
14	WALK2 WALK2	Lorry	Car
15	JUMP FALL	Horse jumping down	Bomb
16	FALL FLY2	Man and broken drainpipe	Aeroplane
17	ROLL ROLL	Hoop	Bowl
18	THROW PUSH	Ball	Pram
19	WALK2 FLY1	Car	Bee
20	FLY1 FLY2	Bird	Helicopter
21	JUMP WALK2	Girl	Lorry
22	THROW FALL	Football	Bomb
23	PUSH FLOAT	Hay cart	Clouds
24	JUMP JUMP	Horse jumping down	Girl
25	CARRY FLY1	Carried pole	Bee
26	FLY2 THROW	Aeroplane	Ball
27	WALK1 WALK2	Bull	Car
28	THROW JUMP	Ball	Girl
29	ROLL PUSH	Bowl	Pram
30	FLOAT ROLL	Balloon	Hoop
31	CARRY CARRY	People in train	Carried pole
32	WALK1 WALK1	Man	Bull
33	FLOAT WALK2	Clouds	Lorry
34	FALL PUSH	Man and broken drainpipe	Hay cart
35	CARRY THROW	Carried pole	Ball
36	WALK2 THROW	Car	Football
37	FLOAT FLY2	Balloon	Helicopter
38	FALL FALL	Bomb	Man and broken drainpipe
39	JUMP CARRY	Horse jumping down	People in train
40	PUSH PUSH	Pram	Hay cart
41	THROW THROW	Ball	Football
42	FLOAT CARRY	Clouds	Carried pole
43	PUSH WALK1	Hay cart	Bull
44	JUMP FLOAT	Girl	Balloon
45	FLY1 FLY1	Bird	Bee
46	WALK1 ROLL	Man	Bowl
47	FLOAT THROW	Clouds	Football
48	ROLL JUMP	Hoop	Horse jumping down
49	FALL FLOAT	Man and broken drainpipe	Balloon
50	FLY1 ROLL	Bee	Bowl

Table V.2: Randomly ordered examples for matching task 2 to test role of animacy in the commonsense understanding of motion

Example number	Example Name	Pictures representing the classes of motion for comparison	
1	TRAINING EXAMPLE	Cart	Tincan
2	CARRY I.I.	People in train	Sand in lorry
3	PUSH I.I	Car towed	Earth moved
4	FLY A.A.	Pigeon	Bee
5	JUMP I.A.	Pogostick	Girl
6	FLY I.A.	Plane	Pigeon
7	FALL A.A.	Drainpipe	Girl/tree
8	THROW A.A.	Football	Cricketball
9	WALK A.A.	Bull	Athlete
10	CARRY I.A.	People in train	Pole
11	JUMP A.A.	Horse	Girl
12	WALK I.A.	Car	Bull
13	PUSH A.A.	Haywain	Pram
14	FLY I.I.	Plane	Helicopter
15	PUSH I.A.	Car towed	Haywain
16	FLOAT I.A.	Clouds	Butterfly
17	ROLL I.A.	Hoop	Skater
18	THROW I.A.	Rocket	Football
19	JUMP I.I.	Pogostick	Jackinthebox
20	ROLL I.I.	Hoop	Bowl
21	FLOAT I.I.	Bird gliding	Butterfly
22	CARRY A.A.	Pole	Washing basket
23	FLOAT I.I.	Balloon	Clouds
24	WALK I.I.	Car	Lorry
25	ROLL A.A.	Skater	Skier
26	FALL I.I.	Bomb	Nest
27	THROW I.I.	Rocket	Bullets
28	FALL I.A.	Drainpipe	Nest

A = ANIMATE I = INANIMATE

Table V.3: Randomly ordered examples for matching task 3 to test role of animacy in the commonsense understanding of motion

Example Number	Example Name	Pictures
1	TRAINING EXAMPLE	Go cart and tin can
2	CARRY FLY AND WALK	Passengers in Helicopter and lorry
3	CARRY FALL AND PUSH	Eggs in nest and pram
4	CARRY FLY AND CARRY FLY	Passengers in aeroplane and passengers in Helicopter
5	CARRY FALL AND CARRY FLOAT	Washing in basket and passengers in glider
6	CARRY PUSH AND CARRY FLOAT	Baby in pram and passengers in balloon
7	CARRY FALL AND FLOAT	Eggs in Nest and Balloon
8	CARRY PUSH AND PUSH	Earth in wheelbarrow and haycart
9	CARRY WALK AND CARRY FLOAT	Passengers in train and passengers in glider
10	CARRY FLOAT AND CARRY FLOAT	Passengers in balloon and passengers in glider
11	CARRY FALL AND WALK	Washing in basket and car
12	CARRY PUSH AND CARRY FALL	Baby in pram and eggs in nest
13	CARRY WALK In AND CARRY WALK Held	Passengers in bus and man holding pole
14	CARRY PUSH AND CARRY WALK	Earth in wheelbarrow and passengers in train
15	CARRY FLY In AND CARRY FLY Held	Passengers in aerplane and bird holding twig
16	CARRY PUSH AND WALK	Baby in Pram and athlete
17	CARRY WALK AND FLOAT	Passengers in Bus and cloud
18	CARRY WALK AND CARRY FALL	Passengers in train and eggs in nest
19	CARRY FALL In and CARRY FALL Held	Washing in basket and girl holding book
20	CARRY FLY AND FLOAT	Passengers in helicopter and balloon
21	CARRY PUSH AND FALL	Earth in Wheelbarrow and Bomb
22	CARRY FLY AND CARRY FALL	Passengers in aeroplane and eggs in nest
23	CARRY PUSH AND FLY	Baby in Pram and bird
24	CARRY WALK AND FLY	Passengers in Train and Bee
25	CARRY PUSH In AND CARRY PUSH Held	Earth in Wheelbarrow and baby holding rattle in pram
26	CARRY FLY AND CARRY FLOAT	Passengers in helicopter and passengers in balloon
27	CARRY WALK AND CARRY WALK	Passengers in train and passengers in bus
28	CARRY FLOAT In AND CARRY FLOAT Held	Passengers in glider and man on handglider
29	CARRY PUSH AND FLOAT	Baby in Pram and balloon
30	CARRY FALL AND FALL	Washing in basket and man falling off drainpipe
31	CARRY PUSH AND CARRY PUSH	Baby in Pram and earth in wheelbarrow
32	CARRY WALK AND WALK	Passengers in Bus and lorry
33	CARRY FALL AND FLY	Eggs in Nest and Helicopter
34	CARRY WALK AND CARRY FLY	Passengers in train and passengers in aeroplane
35	CARRY FLY AND FLY	Passengers in helicopter and aeroplane
36	CARRY PUSH AND CARRY FLY	Earth in wheelbarrow an passengers in aeroplane
37	CARRY WALK AND FALL	Passengers in bus and man falling off drainpipe
38	CARRY FALL AND CARRY FALL	Eggs in nest and washing in basket
39	CARRY FLY AND PUSH	Passengers in aeroplane and haycart
40	CARRY FLOAT AND FLOAT	Passengers in balloon and balloon
41	CARRY WALK AND PUSH	Passengers in train and haycart
42	CARRY FLY AND FALL	Passengers in aeroplane and man falling off drainpipe.

APPENDIX VI

SUMMARY OF RESULTS FOR MATCHING TASK 1
(SEE CHAPTER 8)

Table VI.1: Summary of Theoretical Scores matched with average score of population tested

EXAMPLE NUMBER	SCORE 1 - VERY ALIKE (0 DIFFERENCE)	AVERAGE PUPILS RESPONSES
5	FLY2 FLY2	1.53
11	FLOAT FLOAT	1.97
14	WALK2 WALK2	1.17
17	ROLL ROLL	1.74
20	FLY1 FLY2	2.23
24	JUMP JUMP	1.50
27	WALK1 WALK2	2.87
31	CARRY CARRY	2.88
32	WALK1 WALK1	1.91
38	FALL FALL	2.23
40	PUSH PUSH	1.74
41	THROW THROW	1.47
45	FLY1 FLY1	1.26
	SCORE 2 - A BIT ALIKE (1 DIFFERENCE)	
13	ROLL THROW	1.67
19	WALK 2 FLY	3.31
28	THROW JUMP	2.44
29	ROLL PUSH	2.32
43	PUSH WALK	2.63
49	FALL FLOAT	3.62
	SCORE 3 - A BIT DIFFERENT (2 DIFFERENCES)	
3	CARRY ROLL	2.60
6	ROLL FALL	3.17
7	PUSH FLY	3.68
9	JUMP FLY2	3.45
10	CARRY PUSH	2.64
12	WALK CARRY	3.15
15	JUMP FALL	3.43
18	THROW PUSH	2.92
21	JUMP WALK2	3.45
30	FLOAT ROLL	3.22
35	CARRY THROW	2.38
39	JUMP CARRY	3.30
44	JUMP FLOAT	3.19
46	WALK ROLL	3.05
47	FLOAT THROW	3.25
48	ROLL JUMP	3.32
	SCORE 4 - VERY DIFFERENT (3 DIFFERENCES)	
2	PUSH JUMP	2.8
4	FALL CARRY	3.5
8	WALK2 FALL	3.6
16	FALL FLY2	3.5
22	THROW FALL	2.9
23	PUSH FLOAT	3.57
25	CARRY FLY	3.35
26	FLY2 THROW	2.99
33	FLOAT WALK2	3.59
34	FALL PUSH	3.45
36	WALK2 THROW	3.11
37	FLOAT FLY2	2.63
42	FLOAT CARRY	3.29
50	FLY ROLL	3.48

Table VI.2: Comparison of theoretical score with average value of 7 year olds responses

EXAMPLE NUMBER	SCORE 1 - VERY ALIKE (0 DIFFERENCE)	7 YEAR OLD PUPILS RESPONSES
5	FLY2 FLY2	1.72
11	FLOAT FLOAT	2.47
14	WALK2 WALK2	1.25
17	ROLL ROLL	2.25
20	FLY1 FLY2	2.52
24	JUMP JUMP	1.9
27	WALK1 WALK2	2.8
31	CARRY CARRY	2.87
32	WALK1 WALK1	2.52
38	FALL FALL	2.8
40	PUSH PUSH	1.92
41	THROW THROW	1.95
45	FLY1 FLY1	1.67
	SCORE 2 - A BIT ALIKE (1DIFFERENCE)	
13	ROLL THROW	2.22
19	WALK 2 FLY	3.62
28	THROW JUMP	2.15
29	ROLL PUSH	2.8
43	PUSH WALK	2.75
49	FALL FLOAT	3.25
	SCORE 3 - A BIT DIFFERENT (2 DIFFERENCES)	
18	PUSH THROW	3.5
3	CARRY ROLL	3.00
6	ROLL FALL	3.87
7	PUSH FLY	3.77
9	JUMP FLY2	3.67
10	CARRY PUSH	2.95
12	WALK CARRY	3.32
15	JUMP FALL	3.7
18	THROW PUSH	3.5
21	JUMP WALK2	3.67
30	FLOAT ROLL	3.3
35	CARRY THROW	2.75
39	JUMP CARRY	3.3
44	JUMP FLOAT	3.1
46	WALK ROLL	3.15
47	FLOAT THROW	3.37
48	ROLL JUMP	3.37
	SCORE 4 - VERY DIFFERENT (3 DIFFERENCES)	
2	PUSH JUMP	2.72
4	FALL CARRY	3.82
8	WALK2 FALL	3.7
16	FALL FLY2	3.67
22	THROW FALL	3.52
23	PUSH FLOAT	3.35
25	CARRY FLY	3.3
26	FLY2 THROW	3.22
33	FLOAT WALK2	3.52
34	FALL PUSH	3.52
36	WALK2 THROW	3.2
37	FLOAT FLY2	2.82
42	FLOAT CARRY	3.4
50	FLY ROLL	3.32

Table VI.3: Comparison of theoretical score with average value of 10 year olds responses.

EXAMPLE NUMBER	SCORE 1 - VERY ALIKE (0 DIFFERENCE)	10 YEAR OLD PUPILS RESPONSES
5	FLY2 FLY2	1.47
11	FLOAT FLOAT	1.95
14	WALK2 WALK2	1.37
17	ROLL ROLL	1.7
20	FLY1 FLY2	2.3
24	JUMP JUMP	1.52
27	WALK1 WALK2	2.82
31	CARRY CARRY	3.47
32	WALK1 WALK1	2.05
38	FALL FALL	2.55
40	PUSH PUSH	1.85
41	THROW THROW	1.45
45	FLY1 FLY1	1.2
	SCORE 2 - A BIT ALIKE (1 DIFFERENCE)	
13	ROLL THROW	1.9
19	WALK 2 FLY	3.37
28	THROW JUMP	2.37
29	ROLL PUSH	2.47
43	PUSH WALK	2.42
49	FALL FLOAT	3.35
	SCORE 3 - A BIT DIFFERENT (2 DIFFERENCES)	
3	CARRY ROLL	2.95
6	ROLL FALL	3.22
7	PUSH FLY	3.55
9	JUMP FLY2	3.35
10	CARRY PUSH	2.62
12	WALK CARRY	2.8
15	JUMP FALL	3.42
18	THROW PUSH	3.1
21	JUMP WALK2	3.47
30	FLOAT ROLL	3.15
35	CARRY THROW	2.32
39	JUMP CARRY	3.22
44	JUMP FLOAT	3.02
46	WALK ROLL	2.97
47	FLOAT THROW	3.32
48	ROLL JUMP	3.07
	SCORE 4 - VERY DIFFERENT (3 DIFFERENCES)	
2	PUSH JUMP	3.1
4	FALL CARRY	3.57
8	WALK2 FALL	3.65
16	FALL FLY2	3.3
22	THROW FALL	2.55
23	PUSH FLOAT	3.35
25	CARRY FLY	3.25
26	FLY2 THROW	2.75
33	FLOAT WALK2	3.47
34	FALL PUSH	3.57
36	WALK2 THROW	3.05
37	FLOAT FLY2	2.72
42	FLOAT CARRY	3.32
50	FLY ROLL	3.3

Table VI.4: Comparison of theoretical score with average value of 12 year olds responses.

EXAMPLE NUMBER	SCORE 1 - VERY ALIKE (0 DIFFERENCE)	12 YEAR OLD PUPILS RESPONSES
5	FLY2 FLY2	1.21
11	FLOAT FLOAT	2.00
14	WALK2 WALK2	1.07
17	ROLL ROLL	1.78
20	FLY1 FLY2	2.1
24	JUMP JUMP	1.43
27	WALK1 WALK2	2.89
31	CARRY CARRY	2.92
32	WALK1 WALK1	1.83
38	FALL FALL	2.18
40	PUSH PUSH	1.65
41	THROW THROW	1.38
45	FLY1 FLY1	1.2
	SCORE 2 - A BIT ALIKE (1 DIFFERENCE)	
13	ROLL THROW	1.56
19	WALK 2 FLY	3.41
28	THROW JUMP	2.45
29	ROLL PUSH	2.14
43	PUSH WALK	2.85
49	FALL FLOAT	3.45
	SCORE 3 - A BIT DIFFERENT (2 DIFFERENCES)	
3	CARRY ROLL	2.65
6	ROLL FALL	3.07
7	PUSH FLY	3.72
9	JUMP FLY2	3.47
10	CARRY PUSH	2.7
12	WALK CARRY	3.16
15	JUMP FALL	3.25
18	THROW PUSH	2.9
21	JUMP WALK2	3.63
30	FLOAT ROLL	3.18
35	CARRY THROW	2.25
39	JUMP CARRY	3.2
44	JUMP FLOAT	3.1
46	WALK ROLL	3.00
47	FLOAT THROW	3.23
48	ROLL JUMP	3.6
	SCORE 4 - VERY DIFFERENT (3 DIFFERENCES)	
2	PUSH JUMP	2.81
4	FALL CARRY	3.52
8	WALK2 FALL	3.45
16	FALL FLY2	3.41
22	THROW FALL	2.6
23	PUSH FLOAT	3.7
25	CARRY FLY	3.32
26	FLY2 THROW	2.8
33	FLOAT WALK2	3.63
34	FALL PUSH	3.45
36	WALK2 THROW	3.1
37	FLOAT FLY2	2.47
42	FLOAT CARRY	3.16
50	FLY ROLL	3.61

Table VI.5: Comparison of theoretical score with average value of 14 year olds responses.

EXAMPLE NUMBER	SCORE 1 - VERY ALIKE (0 DIFFERENCE)	14 YEAR OLD PUPILS RESPONSES
5	FLY2 FLY2	1.53
11	FLOAT FLOAT	1.69
14	WALK2 WALK2	1.00
17	ROLL ROLL	1.47
20	FLY1 FLY2	2.12
24	JUMP JUMP	1.57
27	WALK1 WALK2	3.02
31	CARRY CARRY	2.9
32	WALK1 WALK1	1.92
38	FALL FALL	2.12
40	PUSH PUSH	1.88
41	THROW THROW	1.47
45	FLY1 FLY1	1.18
	SCORE 2 - A BIT ALIKE (1 DIFFERENCE)	
13	ROLL THROW	1.55
19	WALK 2 FLY	3.16
28	THROW JUMP	2.57
29	ROLL PUSH	2.18
43	PUSH WALK	2.27
49	FALL FLOAT	3.14
	SCORE 3 - A BIT DIFFERENT (2 DIFFERENCES)	
3	CARRY ROLL	2.35
6	ROLL FALL	3.02
7	PUSH FLY	3.65
9	JUMP FLY2	3.35
10	CARRY PUSH	2.69
12	WALK CARRY	3.02
15	JUMP FALL	3.61
18	THROW PUSH	2.61
21	JUMP WALK2	2.39
30	FLOAT ROLL	3.1
35	CARRY THROW	2.41
39	JUMP CARRY	3.2
44	JUMP FLOAT	3.49
46	WALK ROLL	3.12
47	FLOAT THROW	3.33
48	ROLL JUMP	3.31
	SCORE 4 - VERY DIFFERENT (3 DIFFERENCES)	
2	PUSH JUMP	2.65
4	FALL CARRY	3.55
8	WALK2 FALL	3.49
16	FALL FLY2	3.47
22	THROW FALL	3.06
23	PUSH FLOAT	3.76
25	CARRY FLY	3.51
26	FLY2 THROW	3.27
33	FLOAT WALK2	3.67
34	FALL PUSH	3.37
36	WALK2 THROW	3.02
37	FLOAT FLY2	2.39
42	FLOAT CARRY	3.53
50	FLY ROLL	3.65

Table VI.6: Comparison of theoretical score with average value of 16 year olds responses.

EXAMPLE NUMBER	SCORE 1 - VERY ALIKE (0 DIFFERENCE)	16 YEAR OLD PUPILS RESPONSES
5	FLY2 FLY2	1.7
11	FLOAT FLOAT	1.72
14	WALK2 WALK2	1.15
17	ROLL ROLL	1.52
20	FLY1 FLY2	2.1
24	JUMP JUMP	1.05
27	WALK1 WALK2	2.82
31	CARRY CARRY	2.25
32	WALK1 WALK1	1.25
38	FALL FALL	1.5
40	PUSH PUSH	1.42
41	THROW THROW	1.1
45	FLY1 FLY1	1.05
	SCORE 2 - A BIT ALIKE (1 DIFFERENCE)	
13	ROLL THROW	1.12
19	WALK 2 FLY	2.97
28	THROW JUMP	2.65
29	ROLL PUSH	2.02
43	PUSH WALK	2.85
49	FALL FLOAT	3.12
	SCORE 3 - A BIT DIFFERENT (2 DIFFERENCES)	
3	CARRY ROLL	2.05
6	ROLL FALL	2.67
7	PUSH FLY	3.7
9	JUMP FLY2	3.42
10	CARRY PUSH	2.25
12	WALK CARRY	3.47
15	JUMP FALL	3.15
18	THROW PUSH	2.5
21	JUMP WALK2	3.1
30	FLOAT ROLL	3.4
35	CARRY THROW	2.17
39	JUMP CARRY	3.5
44	JUMP FLOAT	3.25
46	WALK ROLL	3.02
47	FLOAT THROW	3.02
48	ROLL JUMP	3.27
	SCORE 4 - VERY DIFFERENT (3 DIFFERENCES)	
2	PUSH JUMP	2.72
4	FALL CARRY	3.05
8	WALK2 FALL	3.7
16	FALL FLY2	3.6
22	THROW FALL	2.77
23	PUSH FLOAT	3.67
25	CARRY FLY	3.37
26	FLY2 THROW	2.92
33	FLOAT WALK2	3.7
34	FALL PUSH	3.32
36	WALK2 THROW	3.15
37	FLOAT FLY2	2.77
42	FLOAT CARRY	3.02
50	FLY ROLL	3.55

Table VI.7: Examples from 7, 10 and 12 year olds showing the computed value of standard deviation/maximum standard deviation

Example Number	Example Name	Standard deviation/ Standard max. seven year olds	Standard deviation/ Standard max. ten year olds	Standard deviation/ Standard max. twelve year olds
1	PUSH THROW	0.95	0.55	0.56
2	PUSH JUMP	0.59	0.71	0.59
3	CARRY ROLL	0.57	0.71	0.51
4	FALL CARRY	0.76	0.67	0.75
5	FLY2 FLY2	0.62	0.61	0.68
6	ROLL FALL	0.93	0.55	0.58
7	PUSH FLY1	0.76	0.66	0.66
8	WALK2 FALL	0.67	0.59	0.63
9	JUMP FLY2	0.64	0.71	0.64
10	CARRY PUSH	0.71	0.67	0.62
11	FLOAT FLOAT	0.66	0.62	0.54
12	WALK1 CARRY	0.60	0.71	0.59
13	ROLL THROW	0.66	0.63	0.56
14	WALK2 WALK2	0.75	0.57	0.73
15	JUMP FALL	0.61	0.77	0.64
16	FALL FLY2	0.60	0.57	0.65
17	ROLL ROLL	0.75	0.60	0.55
18	THROW PUSH	0.80	0.54	0.60
19	WALK2 FLY1	0.88	0.70	0.63
20	FLY1 FLY2	0.61	0.60	0.53
21	JUMP WALK2	0.54	0.62	0.59
22	THROW FALL	0.61	0.57	0.54
23	PUSH FLOAT	0.83	0.68	0.50
24	JUMP JUMP	0.77	0.69	0.65
25	CARRY FLY1	0.64	0.57	0.50
26	FLY2 THROW	0.68	0.65	0.62
27	WALK1 WALK2	0.73	0.65	0.62
28	THROW JUMP	0.69	0.49	0.41
29	ROLL PUSH	0.66	0.68	0.59
30	FLOAT ROLL	0.62	0.57	0.62
31	CARRY CARRY	0.74	0.68	0.72
32	WALK1 WALK1	0.83	0.64	0.55
33	FLOAT WALK2	0.67	0.59	0.68
34	FALL PUSH	0.57	0.70	0.65
35	CARRY THROW	0.67	0.60	0.56
36	WALK2 THROW	0.69	0.68	0.52
37	FLOAT FLY2	0.67	0.54	0.61
38	FALL FALL	0.79	0.76	0.83
39	JUMP CARRY	0.69	0.60	0.52
40	PUSH PUSH	0.70	0.71	0.64
41	THROW THROW	0.74	0.62	0.58
42	FLOAT CARRY	0.69	0.65	0.62
43	PUSH WALK1	0.73	0.68	0.64
44	JUMP FLOAT	0.71	0.63	0.63
45	FLY1 FLY1	0.82	0.55	0.79
46	WALK1 ROLL	0.56	0.46	0.48
47	FLOAT THROW	0.63	0.63	0.61
48	ROLL JUMP	0.65	0.60	0.61
49	FALL FLOAT	0.74	0.59	0.59
50	FLY1 ROLL	0.69	0.69	0.54

Table VI.8: Examples from 14 and 16 year olds showing the computed value of standard deviation/maximum standard deviation

Example Number	Example Name	Standard deviation/ Standard max. fourteen year olds	Standard deviation/ Standard max. sixteen year olds
1	PUSH THROW	0.66	0.62
2	PUSH JUMP	0.74	0.78
3	CARRY ROLL	0.67	0.64
4	FALL CARRY	0.71	0.92
5	FLY2 FLY2	0.68	0.80
6	ROLL FALL	0.70	0.80
7	PUSH FLY1	0.66	0.82
8	WALK2 FALL	0.72	0.79
9	JUMP FLY2	0.69	0.67
10	CARRY PUSH	0.68	0.68
11	FLOAT FLOAT	0.63	0.72
12	WALK1 CARRY	0.67	1.38
13	ROLL THROW	0.56	0.66
14	WALK2 WALK2	0.00	0.72
15	JUMP FALL	0.74	0.65
16	FALL FLY2	0.66	0.61
17	ROLL ROLL	0.58	0.70
18	THROW PUSH	0.61	0.57
19	WALK2 FLY1	0.70	0.83
20	FLY1 FLY2	0.60	0.65
21	JUMP WALK2	0.65	0.63
22	THROW FALL	0.75	0.74
23	PUSH FLOAT	0.74	0.61
24	JUMP JUMP	0.62	0.55
25	CARRY FLY1	0.62	0.53
26	FLY2 THROW	0.73	0.58
27	WALK1 WALK2	0.73	0.62
28	THROW JUMP	0.61	0.62
29	ROLL PUSH	0.68	0.69
30	FLOAT ROLL	0.73	0.67
31	CARRY CARRY	0.73	0.80
32	WALK1 WALK1	0.60	0.64
33	FLOAT WALK2	0.79	0.67
34	FALL PUSH	0.65	0.69
35	CARRY THROW	0.63	0.72
36	WALK2 THROW	0.68	0.67
37	FLOAT FLY2	0.54	0.59
38	FALL FALL	0.81	0.80
39	JUMP CARRY	0.68	0.66
40	PUSH PUSH	0.74	0.77
41	THROW THROW	0.71	0.56
42	FLOAT CARRY	0.59	0.75
43	PUSH WALK1	0.68	0.62
44	JUMP FLOAT	0.86	0.55
45	FLY1 FLY1	0.80	0.55
46	WALK1 ROLL	0.60	0.5
47	FLOAT THROW	0.74	0.68
48	ROLL JUMP	0.72	0.69
49	FALL FLOAT	0.60	0.73
50	FLY1 ROLL	0.69	0.62

APPENDIX VII

SUMMARY OF RESULTS FOR MATCHING TASK 2
(SEE CHAPTER 9)

Table VII.1: Theoretical scores with animacy allowance compared with actual responses obtained from pupils aged 7 and 10 years plus mean score

Example Number	Name of Example	Theoretical Score	Mean Score	Seven Score	Ten Score
5	FLY2 FLY2	1	1.53	1.72	1.47
11	FLOAT FLOAT	1	1.97	2.47	1.95
14	WALK2 WALK2	1	1.17	1.25	1.37
17	ROLL ROLL	1	1.74	2.25	1.70
24	JUMP JUMP	1	1.50	1.90	1.52
32	WALK1 WALK1	1	1.91	2.52	2.05
40	PUSH PUSH	1	1.74	1.92	1.85
41	THROW THROW	1	1.47	1.95	1.45
45	FLY1 FLY1	1	1.26	1.67	1.20
20	FLY1 FLY2	2	2.23	2.52	2.30
7	WALK1 WALK2	2	2.87	2.80	2.82
31	CARRY CARRY	2	2.88	2.87	3.47
38	FALL FALL	2	2.23	2.80	2.55
13	ROLL THROW	2	1.67	2.22	1.90
29	ROLL PUSH	2	2.32	2.80	2.47
19	WALK2 FLY1	3	3.31	3.62	3.37
28	THROW JUMP	3	2.44	2.15	2.37
43	PUSH WALK1	3	2.63	2.75	2.42
49	FALL FLOAT	3	3.62	3.25	3.35
3	CARRY ROLL	3	2.60	3.00	2.95
6	ROLL FALL	3	3.17	3.87	3.22
10	CARRY PUSH	3	2.64	2.95	2.62
12	WALK1 CARRY	3	3.15	3.32	2.80
18	THROW PUSH	3	2.92	3.50	3.10
30	FLOAT ROLL	3	3.22	3.30	3.15
35	CARRY THROW	3	2.38	2.75	2.32
46	WALK1 ROLL	3	3.05	3.15	2.97
47	FLOAT THROW	3	3.25	3.37	3.32
7	PUSH FLY1	4	3.68	3.77	3.55
9	JUMP FLY2	4	3.45	3.67	3.35
15	JUMP FALL	4	3.43	3.70	3.42
21	JUMP WALK2	4	3.45	3.67	3.47
39	JUMP CARRY	4	3.30	3.30	3.32
44	JUMP FLOAT	4	3.19	3.10	3.02
48	ROLL JUMP	4	3.32	3.37	3.07
2	PUSH JUMP	4	2.80	2.72	3.10
4	FALL CARRY	4	3.50	3.82	3.57
8	WALK2 CARRY	4	3.60	3.70	3.65
16	FALL FLY2	4	3.50	3.67	3.30
22	THROW FALL	4	2.90	3.52	2.55
23	PUSH FLOAT	4	3.57	3.35	3.35
26	FLY2 THROW	4	2.99	3.22	2.75
33	FLOAT WALK2	4	3.59	3.52	3.47
36	WALK2 THROW	4	3.11	3.20	3.05
37	FLOAT FLY2	4	2.63	2.82	2.72
42	FLOAT CARRY	4	3.29	3.40	3.32
25	CARRY FLY1	5	3.35	3.30	3.25
34	FALL PUSH	5	3.45	3.52	3.57
50	FLY1 ROLL	5	3.48	3.32	3.30

Table VII.2: Theoretical scores with animacy allowance compared with actual responses obtained from pupils aged 12-16 years

Example Number	Name of Example	Theoretical Score	Twelve Score	Fourteen Score	Sixteen Score
5	FLY2 FLY2	1	1.21	1.53	1.70
11	FLOAT FLOAT	1	2.00	1.69	1.72
14	WALK2 WALK2	1	1.07	1.00	1.50
17	ROLL ROLL	1	1.78	1.47	1.52
24	JUMP JUMP	1	1.43	1.57	1.05
32	WALK1 WALK1	1	1.83	1.92	1.25
40	PUSH PUSH	1	1.65	1.88	1.42
41	THROW THROW	1	1.38	1.47	1.10
45	FLY1 FLY1	1	1.20	1.18	1.05
20	FLY1 FLY2	2	2.10	2.12	2.10
7	WALK1 WALK2	2	2.89	3.02	2.82
31	CARRY CARRY	2	2.92	2.90	2.25
38	FALL FALL	2	2.18	2.12	1.50
13	ROLL THROW	2	1.56	1.55	1.12
29	ROLL PUSH	2	2.14	2.18	2.02
19	WALK2 FLY1	3	3.41	3.16	2.97
28	THROW JUMP	3	2.45	2.57	2.65
43	PUSH WALK1	3	2.85	2.27	2.85
49	FALL FLOAT	3	3.45	3.14	3.12
3	CARRY ROLL	3	2.65	2.35	2.05
6	ROLL FALL	3	3.07	3.02	2.67
10	CARRY PUSH	3	2.70	2.69	2.25
12	WALK1 CARRY	3	3.16	3.02	3.47
18	THROW PUSH	3	2.90	2.61	2.50
30	FLOAT ROLL	3	3.18	3.11	3.40
35	CARRY THROW	3	2.25	2.41	2.17
46	WALK1 ROLL	3	3.00	3.12	3.02
47	FLOAT THROW	3	3.23	3.33	3.02
7	PUSH FLY1	4	3.72	3.65	3.70
9	JUMP FLY2	4	3.47	3.35	3.42
15	JUMP FALL	4	3.25	3.61	3.15
21	JUMP WALK2	4	3.63	3.39	3.10
39	JUMP CARRY	4	3.20	3.20	3.50
44	JUMP FLOAT	4	3.10	3.49	3.25
48	ROLL JUMP	4	3.60	3.31	3.27
2	PUSH JUMP	4	2.81	2.65	2.72
4	FALL CARRY	4	3.52	3.55	3.05
8	WALK2 CARRY	4	3.45	3.49	3.70
16	FALL FLY2	4	3.41	3.47	3.60
22	THROW FALL	4	2.60	3.06	2.77
23	PUSH FLOAT	4	3.70	3.76	3.67
26	FLY2 THROW	4	2.80	3.27	2.92
33	FLOAT WALK2	4	3.63	3.67	3.70
36	WALK2 THROW	4	3.10	3.02	3.15
37	FLOAT FLY2	4	2.47	2.39	2.77
42	FLOAT CARRY	4	3.16	3.53	3.02
25	CARRY FLY1	5	3.32	3.51	3.37
34	FALL PUSH	5	3.45	3.37	3.32
50	FLY1 ROLL	5	3.61	3.65	3.55

Table VII.3: Table to show the standard deviation/standard deviation maximum of each group tested for the Matching Task 2

Example Number	Example Name		Sevens' Standard Deviation/ Standard Deviation Maximum.	Sixteens' Standard Deviation/ Standard Deviation Maximum.
1	"THROW AWAY"		0.93	0.55
2	CARRY	I.I.	0.75	0.73
3	PUSH	I.I.	0.58	0.65
4	FLY	A.A.	0.70	0.55
5	JUMP	I.A.	0.75	0.63
6	FLY	I.A.	0.48	0.73
7	FALL	A.A.	0.68	0.71
8	THROW	A.A.	0.62	0.55
9	WALK	A.A.	0.87	0.72
10	CARRY	I.A.	0.82	0.75
11	JUMP	A.A.	0.82	0.54
12	WALK	I.A.	0.70	0.67
13	PUSH	A.A.	0.57	0.48
14	FLY	I.I.	0.75	0.61
15	PUSH	I.A.	0.67	0.60
16	FLOAT	I.A.	0.69	0.55
17	ROLL	I.A.	0.48	0.62
18	THROW	I.A.	0.72	0.64
19	JUMP	I.I.	0.90	0.54
20	ROLL	I.I.	0.65	0.50
21	FLOAT	I.I.	0.81	0.59
22	CARRY	A.A.	0.89	0.60
23	FLOAT	I.I.	0.63	0.47
24	WALK	I.I.	0.65	0.57
25	ROLL	A.A.	0.63	0.54
26	FALL	I.I.	0.80	0.52
27	THROW	I.I.	0.76	0.57
28	FALL	I.A.	0.74	0.47

APPENDIX VIII

SUMMARY OF RESULTS FOR MATCHING TASK 3 (SEE CHAPTER 10)

Table VIII.1: Table to show the mean values of each age group tested for the CARRY TASK

Example Number	Example Name	Seven Mean	Twelve Mean	Six-teen Mean	Total Mean
2	CARRY FLY AND WALK	2.90	2.79	2.75	2.81
3	CARRY FALL AND PUSH	3.47	3.52	3.72	3.57
4	CARRY FLY AND CARRY FLY	1.63	1.21	1.22	1.35
5	CARRY FALL AND CARRY FLOAT	3.50	2.86	3.44	3.27
6	CARRY PUSH AND CARRY FLOAT	2.77	2.72	3.44	2.98
7	CARRY FALL AND FLOAT	3.23	2.69	3.38	3.10
8	CARRY PUSH AND PUSH	1.77	1.90	1.97	1.88
9	CARRY WALK AND CARRY FLOAT	2.63	2.21	2.22	2.35
10	CARRY FLOAT AND CARRY FLOAT	1.67	1.83	1.81	1.77
11	CARRY FALL AND WALK	3.30	3.38	3.63	3.44
12	CARRY PUSH AND CARRY FALL	3.33	3.17	3.84	3.45
13	CARRY WALK In AND CARRY WALK Held	2.83	2.90	2.75	2.83
14	CARRY PUSH AND CARRY WALK	2.50	2.48	2.25	2.41
15	CARRY FLY In AND CARRY FLY Held	1.70	1.83	1.81	1.78
16	CARRY PUSH AND WALK	2.17	2.24	2.94	2.45
17	CARRY WALK AND FLOAT	3.07	3.03	3.47	3.19
18	CARRY WALK AND CARRY FALL	3.17	3.38	3.47	3.34
19	CARRY FALL In and CARRY FALL Held	2.47	1.86	2.13	2.15
20	CARRY FLY AND FLOAT	2.33	2.21	2.72	2.42
21	CARRY PUSH AND FALL	3.57	3.38	3.63	3.53
22	CARRY FLY AMD CARRY FALL	3.27	3.00	3.47	3.25
23	CARRY PUSH AND FLY	3.23	2.76	3.50	3.16
24	CARRY WALK AND FLY	3.23	3.14	3.56	3.31
25	CARRYPUSHIn AND CARRY PUSH Held	2.50	1.76	1.75	2.00
26	CARRY FLY AND CARRY FLOAT	1.83	1.83	2.09	1.92
27	CARRY WALK AND CARRY WALK	1.23	1.28	1.06	1.19
28	CARRY FLOAT In AND CARRY FLOAT Held	1.50	1.52	1.09	1.37
29	CARRY PUSH AND FLOAT	3.33	3.24	3.63	3.4 0
30	CARRY FALL AND FALL	2.30	1.86	1.66	1.94
31	CARRY PUSH AND CARRY PUSH	1.57	1.45	1.25	1.42
32	CARRY WALK AND WALK	1.40	1.52	1.97	1.63
33	CARRY FALL AND FLY	3.17	2.86	3.66	3.23
34	CARRY WALK AND CARRY FLY	2.87	1.93	1.84	2.21
35	CARRY FLY AND FLY	2.00	1.83	2.19	2.01
36	CARRY PUSH AND CARRY FLY	3.40	2.72	2.94	3.02
37	CARRY WALK AND FALL	3.60	3.31	3.69	3.53
38	CARRY FALL AND CARRY FALL	1.40	1.72	1.41	1.51
39	CARRY FLY AND PUSH	3.43	2.76	3.03	3.07
40	CARRY FLOAT AND FLOAT	1.33	1.34	1.31	1.33
41	CARRY WALK AND PUSH	2.77	2.28	2.38	2.48
42	CARRY FLY AND FALL	3.23	3.14	3.59	3.32

Table VIII.2: Table to show the standard deviation/standard deviation maximum of each age group tested for the CARRY TASK

Example Number	Example Name	Seven Mean	Twelve Mean	Six-teen Mean	Total Mean
2	CARRY FLY AND WALK	0.57	0.52	0.58	0.57
3	CARRY FALL AND PUSH	0.59	0.74	0.83	0.70
4	CARRY FLY AND CARRY FLY	0.80	0.80	0.61	0.71
5	CARRY FALL AND CARRY FLOAT	0.68	0.56	0.71	0.62
6	CARRY PUSH AND CARRY FLOAT	0.71	0.73	0.77	0.71
7	CARRY FALL AND FLOAT	0.70	0.71	0.71	0.69
8	CARRY PUSH AND PUSH	0.58	0.52	0.73	0.61
9	CARRY WALK AND CARRY FLOAT	0.78	0.58	0.75	0.70
10	CARRY FLOAT AND CARRY FLOAT	0.63	0.48	0.64	0.58
11	CARRY FALL AND WALK	0.74	0.67	0.66	0.68
12	CARRY PUSH AND CARRY FALL	0.73	0.68	0.53	0.62
13	CARRY WALK In AND CARRY WALK Held	0.75	0.64	0.61	0.66
14	CARRY PUSH AND CARRY WALK	0.80	0.77	0.61	0.73
15	CARRY FLY In AND CARRY FLY Held	0.82	0.65	0.61	0.69
16	CARRY PUSH AND WALK	0.68	0.63	0.60	0.62
17	CARRY WALK AND FLOAT	0.74	0.61	0.79	0.70
18	CARRY WALK AND CARRY FALL	0.72	0.70	0.66	0.69
19	CARRY FALL In and CARRY FALL Held	0.79	0.72	0.64	0.70
20	CARRY FLY AND FLOAT	0.70	0.63	0.59	0.66
21	CARRY PUSH AND FALL	0.72	0.70	0.55	0.66
22	CARRY FLY AMD CARRY FALL	0.72	0.62	0.58	0.63
23	CARRY PUSH AND FLY	0.76	0.66	0.74	0.70
24	CARRY WALK AND FLY	0.80	0.66	0.57	0.68
25	CARRYPUSHIn AND CARRY PUSH Held	0.84	0.84	0.80	0.78
26	CARRY FLY AND CARRY FLOAT	0.54	0.39	0.53	0.49
27	CARRY WALK AND CARRY WALK	0.63	0.73	0.83	0.68
28	CARRY FLOAT In AND CARRY FLOAT Held	0.86	0.49	0.57	0.61
29	CARRY PUSH AND FLOAT	0.73	0.66	0.61	0.66
30	CARRY FALL AND FALL	0.89	0.72	0.74	0.77
31	CARRY PUSH AND CARRY PUSH	0.75	0.67	0.80	0.72
32	CARRY WALK AND WALK	0.86	0.68	0.68	0.71
33	CARRY FALL AND FLY	0.80	0.56	0.67	0.64
34	CARRY WALK AND CARRY FLY	0.79	0.71	0.56	0.65
35	CARRY FLY AND FLY	0.83	0.59	0.75	0.72
36	CARRY PUSH AND CARRY FLY	0.77	0.56	0.58	0.61
37	CARRY WALK AND FALL	0.78	0.70	0.58	0.67
38	CARRY FALL AND CARRY FALL	0.86	0.80	0.87	0.82
39	CARRY FLY AND PUSH	0.75	0.56	0.61	0.61
40	CARRY FLOAT AND FLOAT	0.84	0.50	0.74	0.70
41	CARRY WALK AND PUSH	0.73	0.59	0.55	0.61
42	CARRY FLY AND FALL	0.74	0.54	0.63	0.62

Sd/Sd Max. = Standard deviation/standard deviation maximum.

Table VIII.3: Comparison of similar identities taken from Matching Task 1

Example Number	Example Name	Sevens' Mean	Twelves' Mean	Sixteens' Mean
5	FLY2 FLY2	1.72	1.21	1.70
11	FLOAT FLOAT	2.47	2.00	1.72
14	WALK WALK	1.25	1.07	1.15
40	PUSH PUSH	1.92	1.65	1.42
38	FALL FALL	2.80	2.18	1.50

Table VIII.4: XY Pairs from Matching Task 1 to correspond to CARRY XY pairs in Matching Task 3

Example Number	Example Name	Sevens' Mean	Twelves' Mean	Sixteens' Mean	Total Mean
2	WALK2 FLY1	3.62	3.41	2.97	3.31
3	FALL PUSH	3.52	3.45	3.32	3.45
11	WALK2 FALL	3.70	3.45	3.70	3.60
16	PUSH WALK1	2.75	2.85	2.85	2.63
21	FALL PUSH	3.52	3.45	3.32	3.45
23	PUSH FLY1	3.77	3.72	3.70	3.68
24	WALK2 FLY1	3.62	3.41	2.97	3.31
33	FLY FALL	3.67	3.41	3.60	3.50
37	WALK2 FALL	3.70	3.45	3.70	3.60
39	PUSH FLY1	3.77	3.72	3.70	3.68
41	PUSH WALK	2.75	2.85	2.85	2.63
42	FLY FALL	3.67	3.41	3.60	3.50

Table VIII.5: XY Pairs from Matching Task 1 to correspond to CARRY X CARRY Y pairs from Matching Task 3

Example Number	Example Name	Sevens' Mean	Twelves' Mean	Sixteens' Mean	Total Mean
5	FALL FLOAT	3.25	3.45	3.12	3.62
26	FLOAT FLY2	2.82	2.47	2.77	2.63
9	FLOAT WALK2	3.52	3.63	3.70	3.59
18	WALK2 FALL	3.70	3.45	3.70	3.60
22	FLY FALL	3.67	3.41	3.60	3.50
34	WALK2 FLY1	3.62	3.41	2.97	3.31
36	PUSH FLY1	3.77	3.72	3.70	3.68
6	PUSH FLOAT	3.35	3.70	3.67	3.57
12	FALL PUSH	3.52	3.45	3.32	3.45
14	PUSH WALK1	2.75	2.85	2.85	2.63

APPENDIX IX

SCATTERPLOTS FOR REFORMULATION OF COMMONSENSE MODEL OF MOTION (SEE CHAPTER 12)

FIG.IX.1 SCATTERPLOT OF MEAN SCORE AGAINST THEORETICAL SCORE OF REVISED VERSION OF THE MODEL.

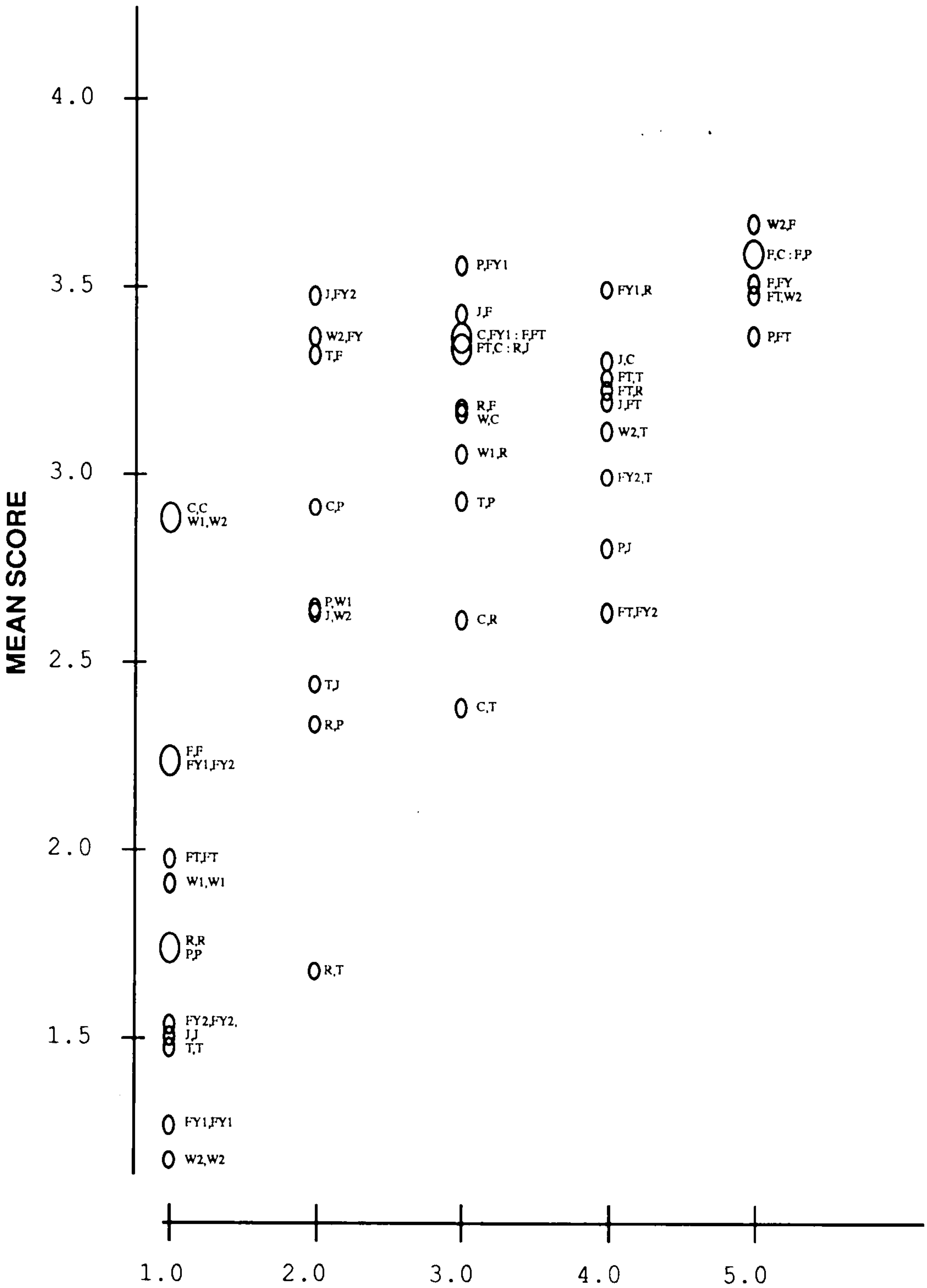


FIG.IX.2 SCATTERPLOT OF SEVENS' MEAN SCORE AGAINST THEORETICAL SCORE OF REVISED VERSION OF THE MODEL.

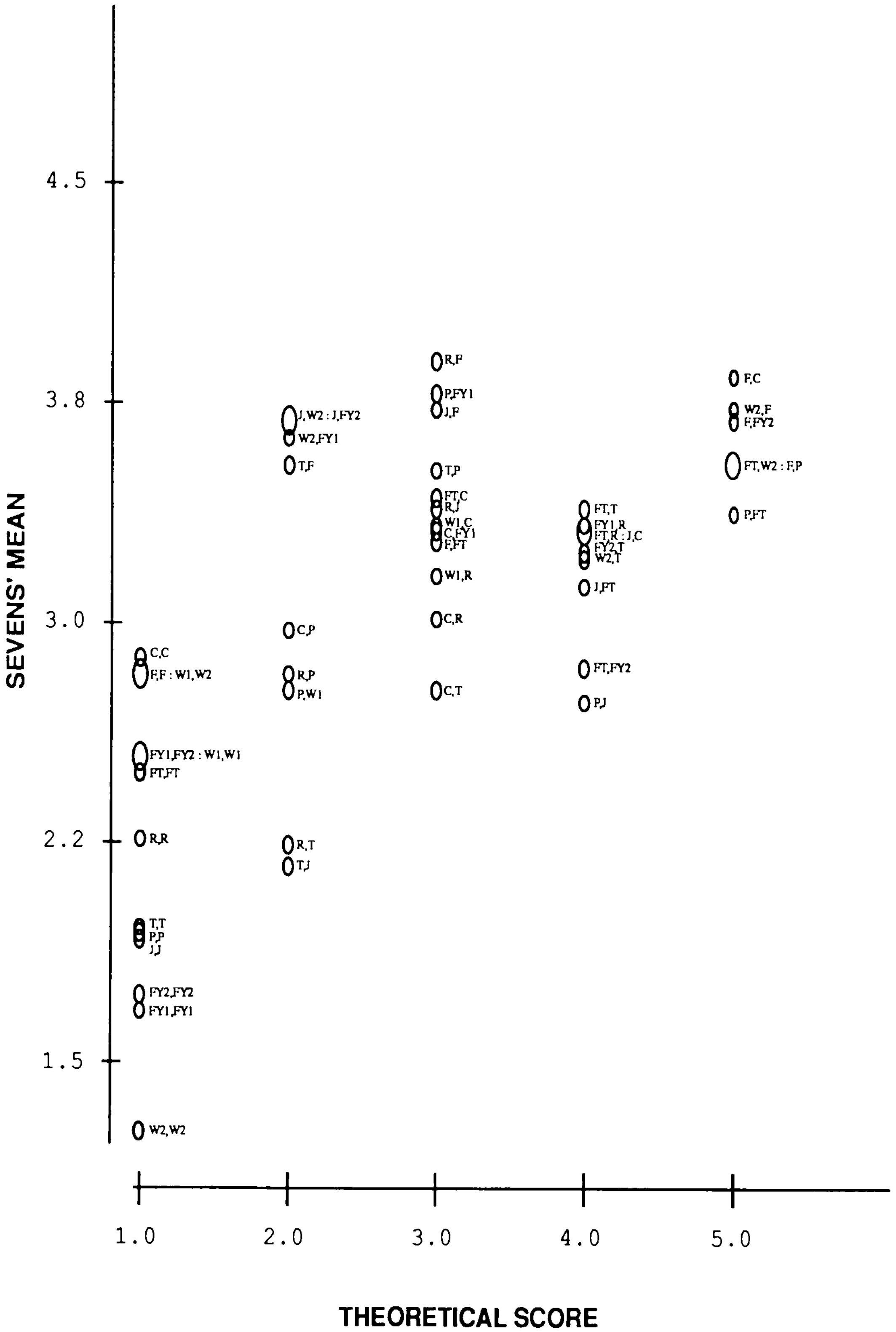


FIG.IX.3 **SCATTERPLOT OF TENS' MEAN SCORE AGAINST THEORETICAL SCORE OF REVISED VERSION OF THE MODEL.**

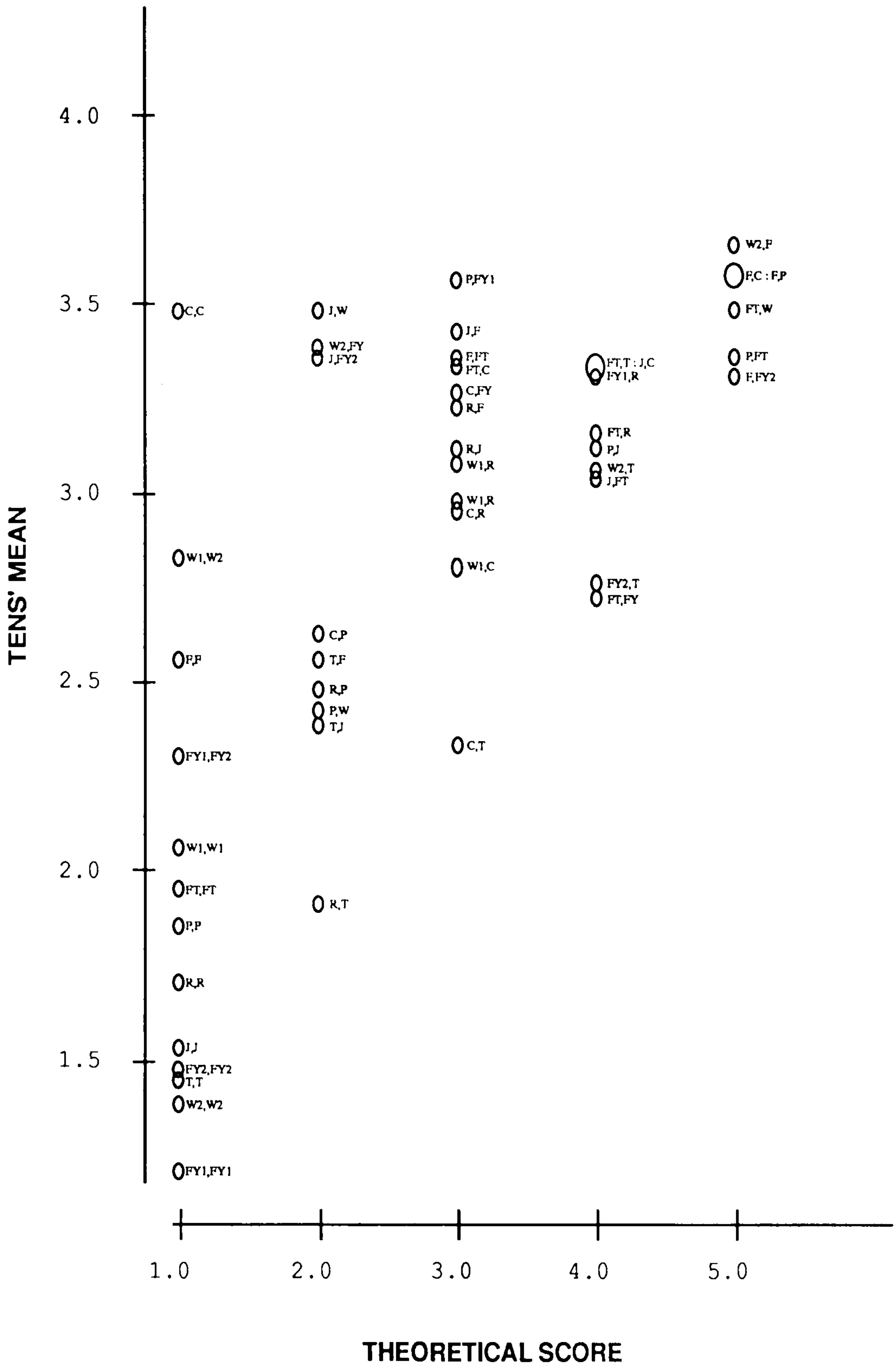


FIG.IX.4 SCATTERPLOT OF TWELVES' MEAN SCORE AGAINST THEORETICAL SCORE OF REVISED VERSION OF THE MODEL.

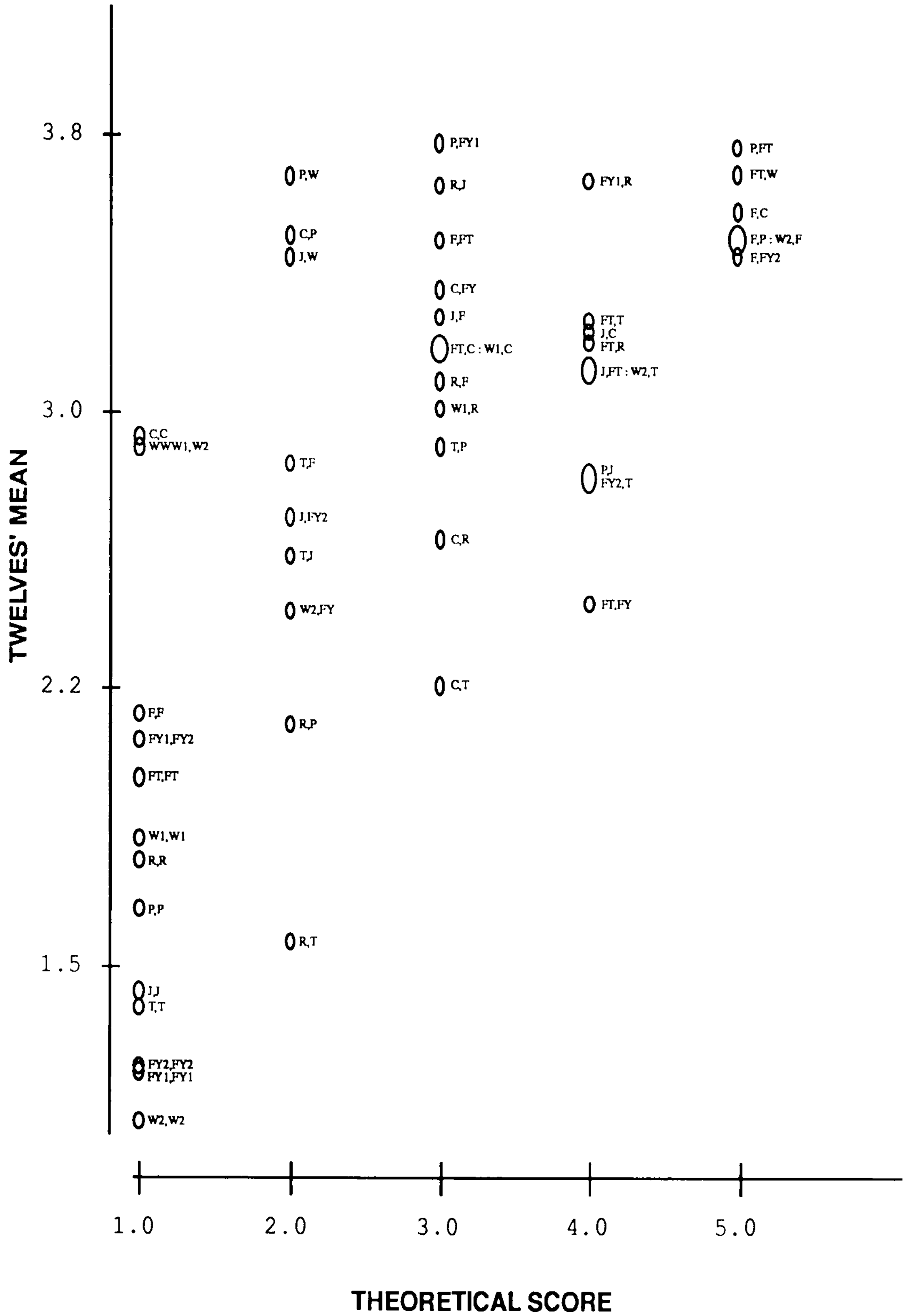


FIG.IX.5 SCATTERPLOT OF FOURTEENS' MEAN SCORE AGAINST THEORETICAL SCORE OF REVISED VERSION OF THE MODEL.

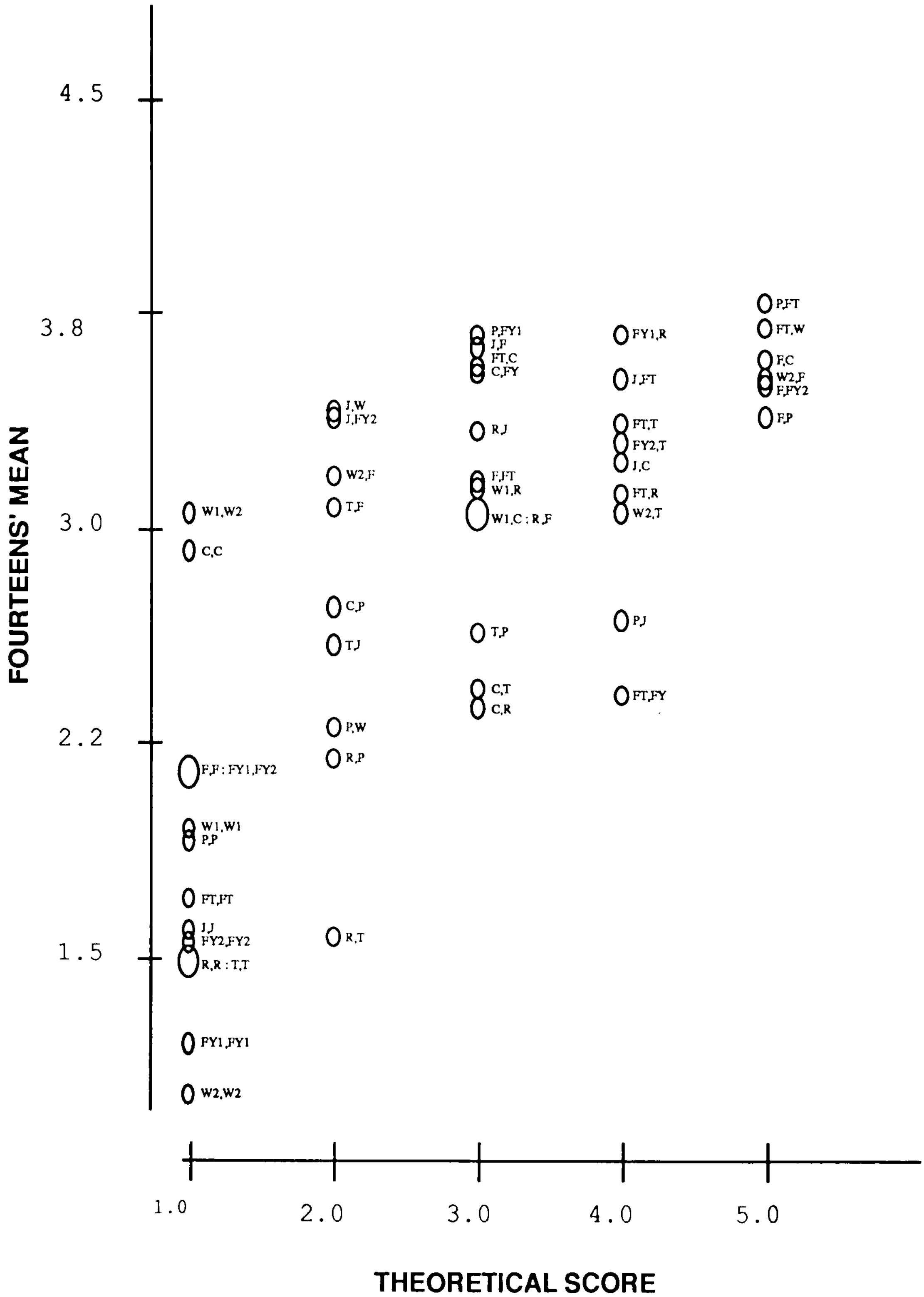


FIG.IX.6 SCATTERPLOT OF SIXTEENS' MEAN SCORE AGAINST THEORETICAL SCORE OF REVISED VERSION OF THE MODEL.

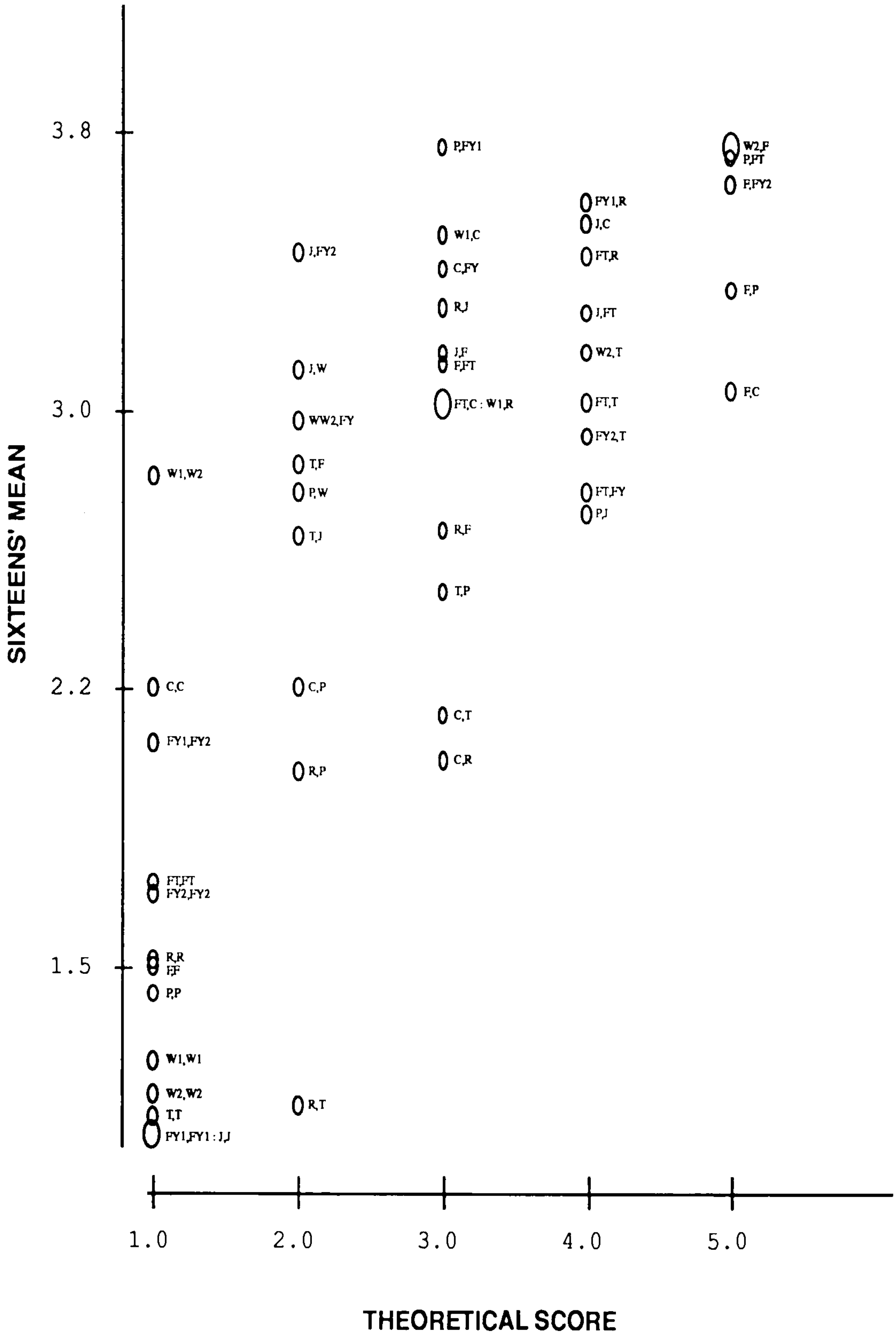


FIG.1X.7 SCATTERPLOT OF MEAN SCORE AGAINST THEORETICAL SCORE OF REVISED VERSION OF THE MODEL, PLUS ANIMACY ALLOWANCE.

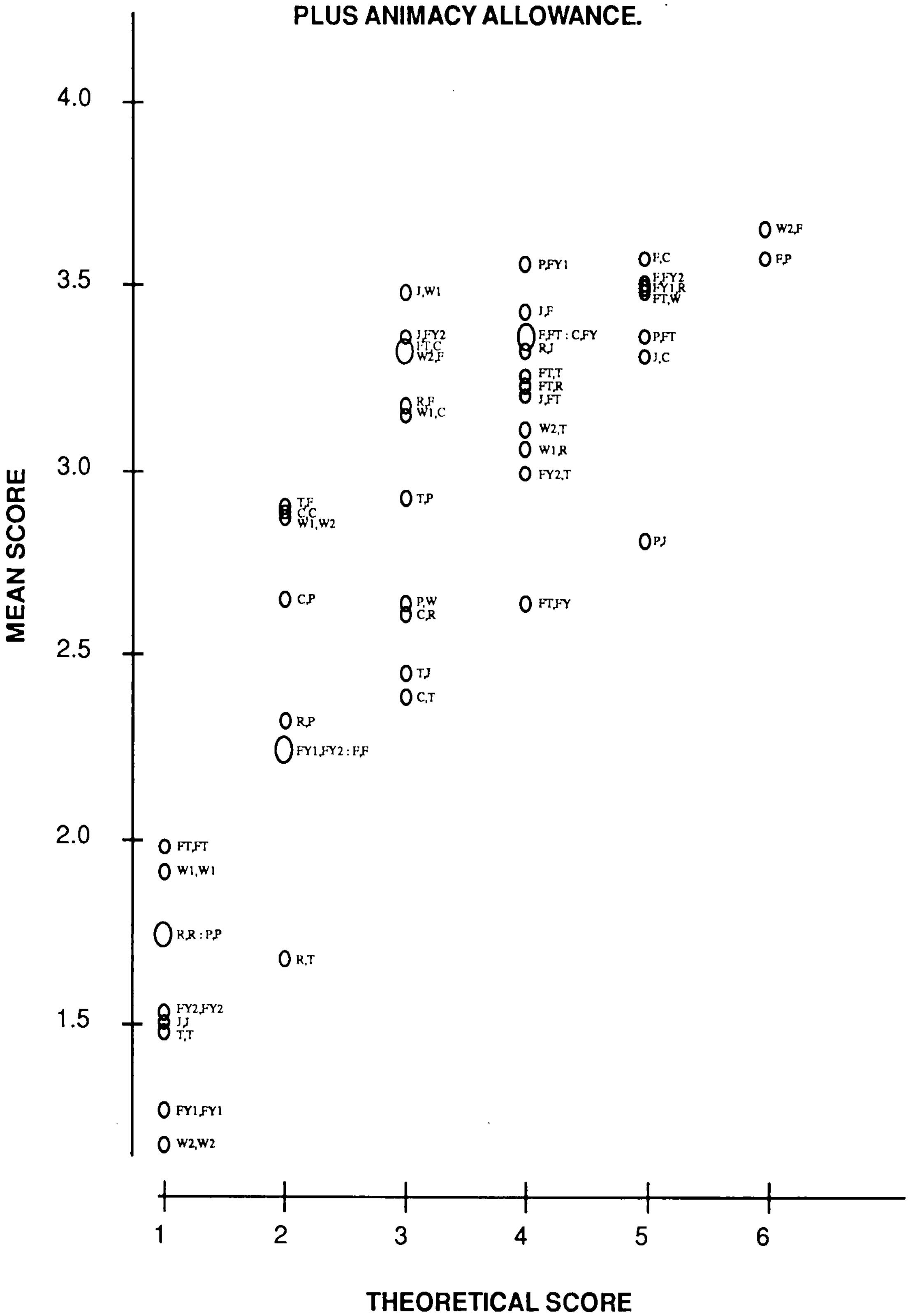


FIG IX.8 SCATTERPLOT OF SEVENS' MEAN SCORE AGAINST THEORETICAL SCORE OF REVISED VERSION OF THE MODEL, PLUS ANIMACY ALLOWANCE.

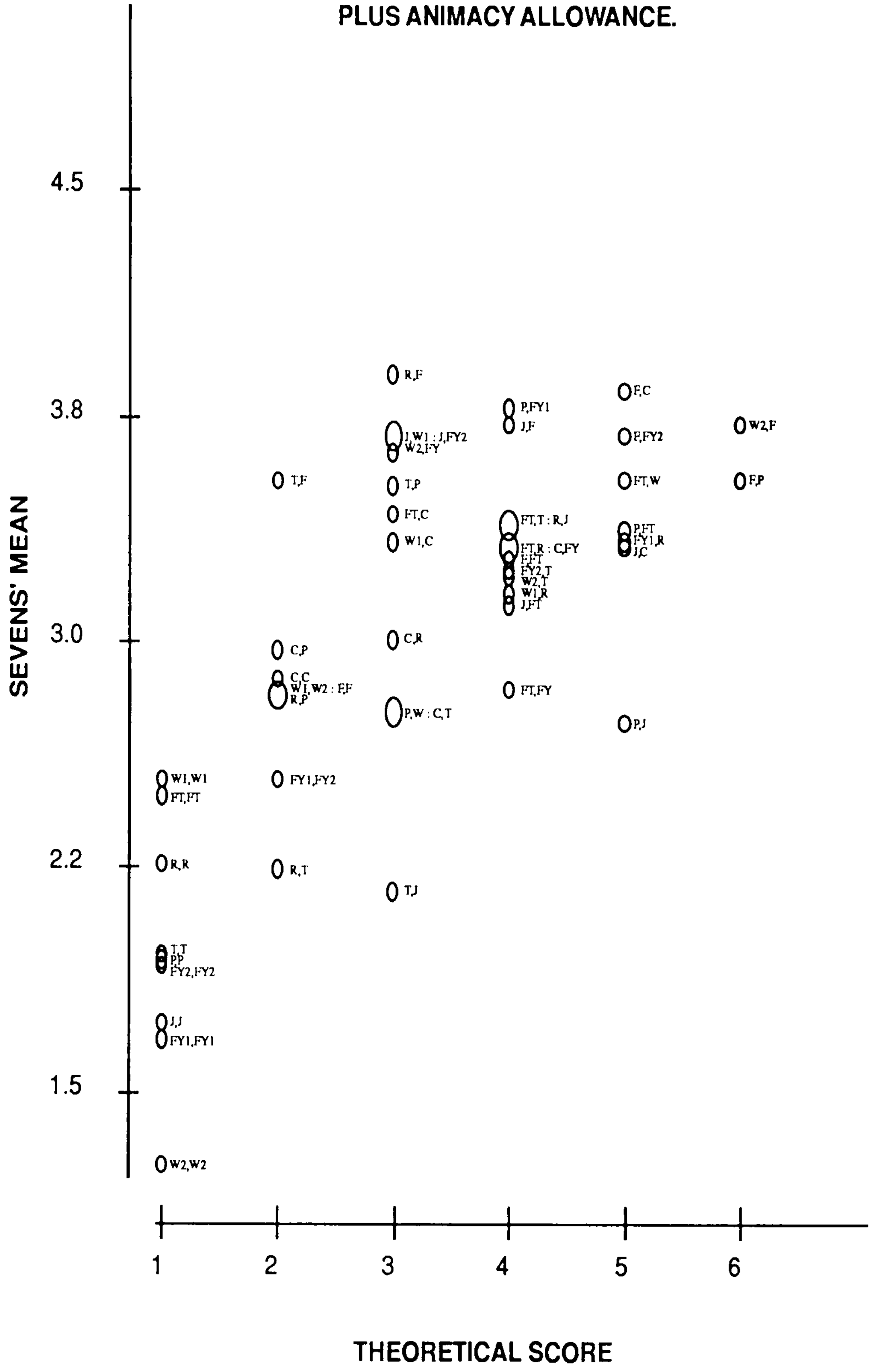


FIG IX.9 SCATTERPLOT OF TENS' MEAN SCORE AGAINST THEORETICAL SCORE OF REVISED VERSION OF THE MODEL, PLUS ANIMACY ALLOWANCE.

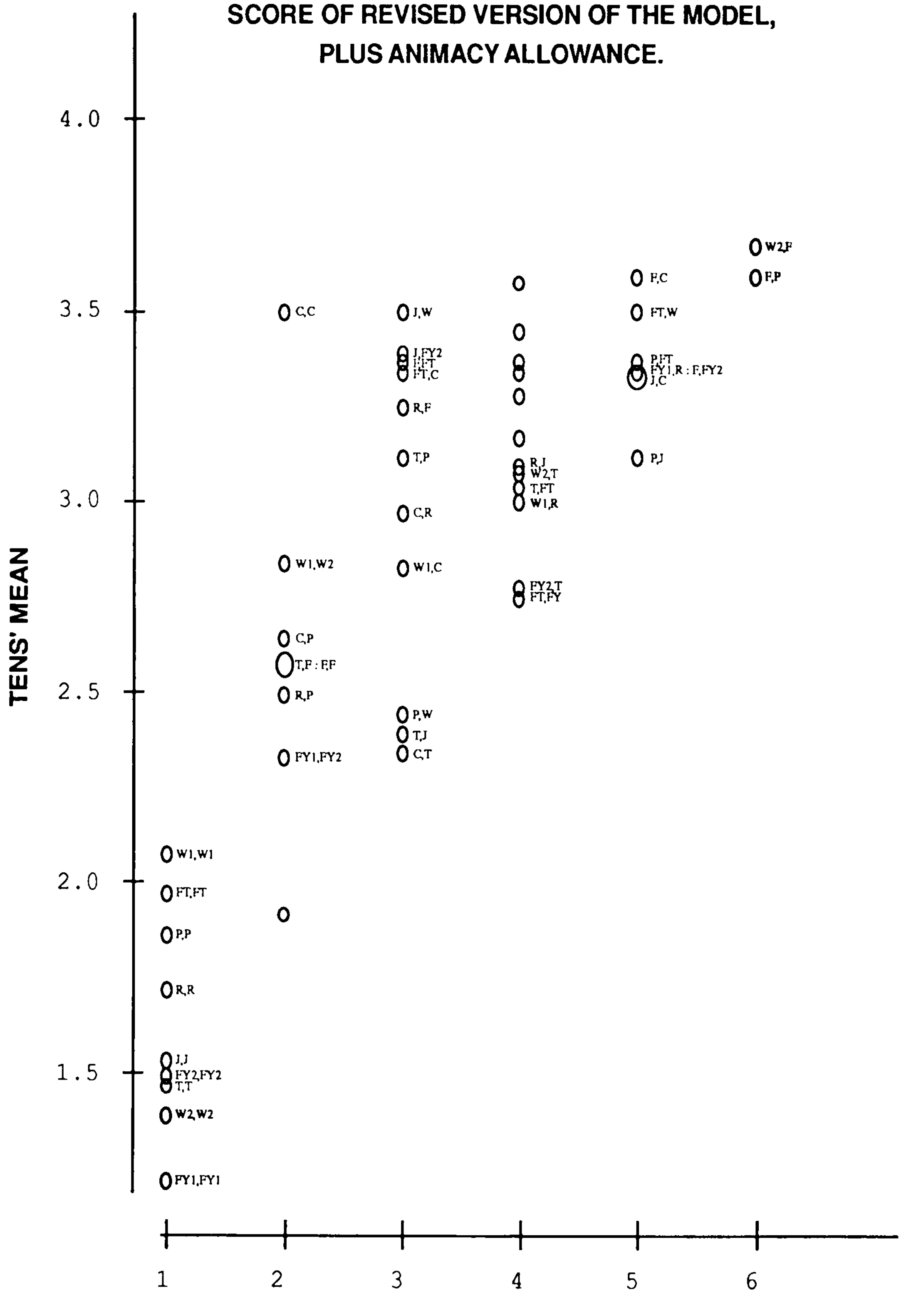


FIG IX. 10 SCATTERPLOT OF TWELVES' MEAN SCORE AGAINST THEORETICAL SCORE OF REVISED VERSION OF THE MODEL, PLUS ANIMACY ALLOWANCE.

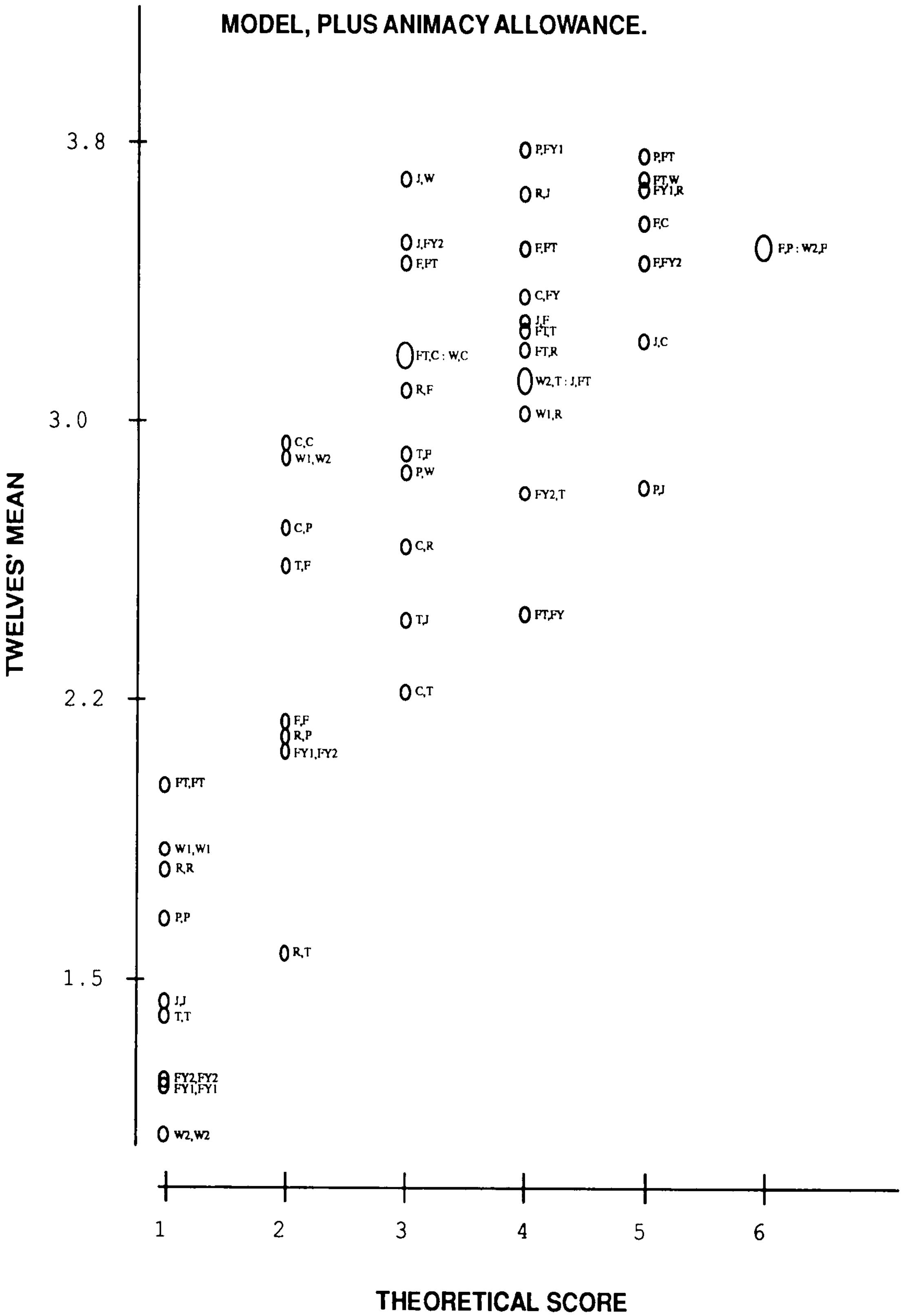


FIG. IX.11 SCATTERPLOT OF FOURTEENS' MEAN SCORE AGAINST THEORETICAL SCORE OF REVISED VERSION OF THE MODEL, PLUS ANIMACY ALLOWANCE.

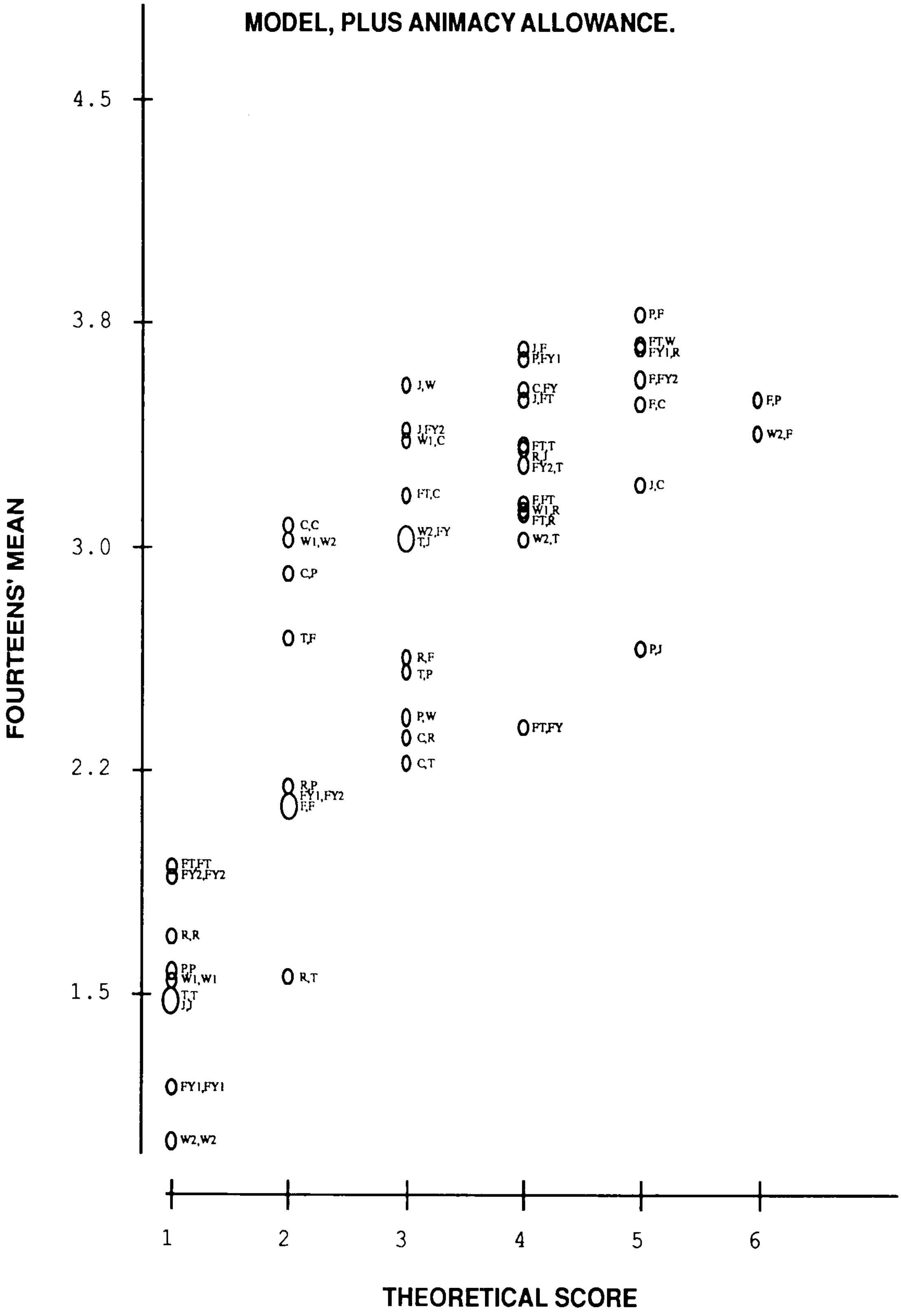
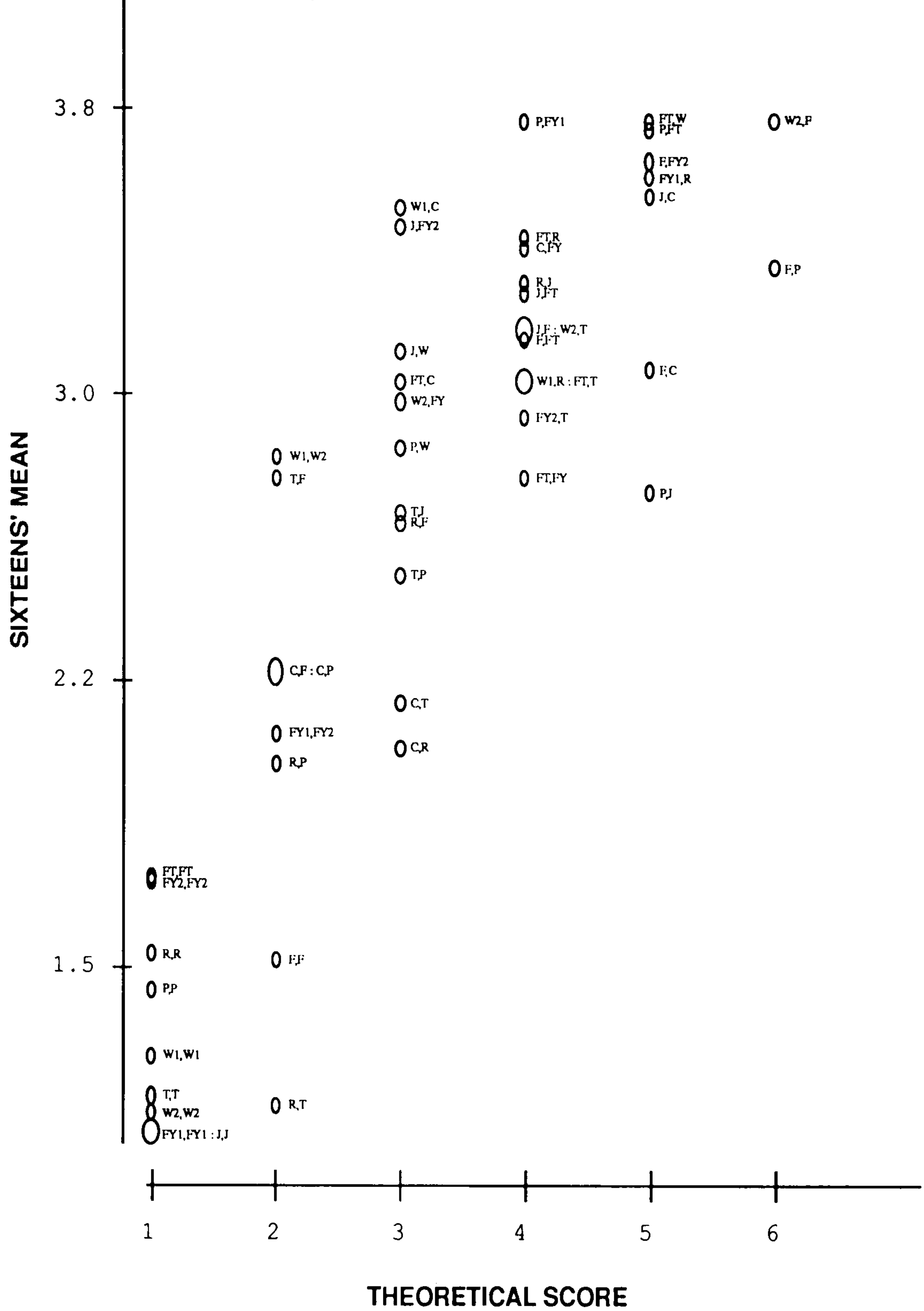


FIG.IX.12 SCATTERPLOT OF SIXTEENS' MEAN SCORE AGAINST THEORETICAL SCORE OF REVISED VERSION OF THE MODEL, PLUS ANIMACY ALLOWANCE.



APPENDIX X

FRAME REPRESENTATION OF STEREOTYPICAL MOTIONS FOR REVISED VERSION OF THE MODEL

THE USE OF FRAMES TO DESCRIBE THE NINE CLASSES OF MOTION

PREDICTED BY THE LATEST VERSION OF THE MODEL OF A COMMONSENSE UNDERSTANDING OF CAUSES OF MOTION

Each class of motion represents a stereotypical action which include a number of expected features. These include the place of motion ie the ground or the air or the nature of the source of movement i.e. living or nonliving . A frame is an economical method of organizing these items or properties allowing the user to make explicit the tacit expectations of a stereotypical situation. The slots allow the default value or normal condition to be entered first followed by the next most likely occurrences. They also clearly state the excluded proprties for each motion. Therefore the frame expresses unambiguously what a series of expectations about any particular motion should be. It has the advantage of also referring to and of excluding the use of other frames in the series. Therefore the frame system can tell you something not only about the moving object itself but what to expect about its source of motion in terms of other frames i.e. classes of motion.

Each frame consists of a number of slots and subslots, with a description of their contents. A template frame is described in Figure X.1below and its pattern followed to describe all nine stereotypical motions.

Figure X.1: A frame template to represent the salient features for each stereotypical motion as described by the commonsense model of motion

SLOT	SUBSLOT	CONTENT
Header		Name of Frame.
Statement		Definition of motion.
Features of the motion:		Description of feature for named motion including default values.
A. Support		Type solid/air/carrier.
B. Animacy		Motion of animate or inanimate object.
C. Effort/control.		
	i. Source	If required then by itself or other.
	ii. Requirement	Is effort required for this motion to take place? Yes/no.
	iii. Control	If effort required - present absent.
D. Original Stereotypes.		Name of primitive action from which this class of motion is most likely to have developed.

The template described in Figure X.1 has been used to provide a more formalised description of the nine stereotypical motions predicted by the commonsense model, (see figures X.2 - X.11). These make explicit not only whether the moving object is expected to be living or non living but also describe certain properties pertinent to the object itself, e.g. the object is expected to be light in the frame representation of FLOAT. The frames also link one type of motion to another e.g. with CARRY, PUSH, THROW and ROLL type motions the effort is provided by an external agent whose motion is expected to belong to the Frame known as WALK. This representation not only clearly divides the motions into separate units but also provides a means of linking them together when this is appropriate.

Figure X.2: Frame representation of the class of motion known as PUSH

SLOT	SUBSLOT	CONTENT
Header		PUSH
Statement		An object has a continual source of motion. The source of this motion shares the same support as the pushed object. The source of effort has autonomous motion and needs to have continued contact with the moving object and it can be infront or behind it.
Features of the motion:		
A. Support		Supported by a solid usually the ground.
		Possible to have solid support above the ground e.g. table and shelf.
		Air excluded, source of motion excluded e.g. CARRY.
B. Animacy		Animate.
		Inanimate possible.
C. Effort/control		
	i. Source	External to object with autonomous motion. Belongs to WALK class of motion.
		FLY and JUMP excluded as motion must take place on solid.
	ii. Requirement	Yes
		No impossible therefore FALL and FLOAT excluded.
	iii. Control	Control
		No control excluded. THROW, ROLL, FALL, FLOAT excluded,
D. Original Stereotypes.		Grasp/Hold and move.

Figure X.3: Frame representation of the class of motion known as FLOAT (A)

SLOT	SUBSLOT	CONTENT
Header		FLOAT (A)
Statement		The object moves in the air (usually slightly falling).
Features of the motion:		
A. Support		None - but not needed. This is a very light object e.g. feather.
		Support excluded.
B. Animacy		Expect Inanimate. Exception spaceman.
C. Effort/control		
	i. Source	Not required.
		Source of effort impossible, CARRY, ROLL, THROW, JUMP, FLY, WALK, PUSH.
	ii. Requirement	No.
		Source of effort impossible, CARRY, ROLL, THROW, JUMP, FLY, WALK, PUSH.
	iii. Control	None.
		Control impossible, WALK and FLY excluded.
D. Original Stereotypes.		Let go.

Figure X.4: Frame representation of the class of motion known as FLOAT (B)

SLOT	SUBSLOT	CONTENT
Header		FLOAT (B)
Statement		The object remains and is moved by the air.
Features of the motion:		
A. Support		Mover - The object inherits the support from the mover which is the AIR.
		Any external source of effort which is also not the supported are impossible, FLY, WALK, JUMP, THROW, ROLL, FALL, PUSH excluded.
B. Animacy		Inanimate e.g. clouds.
		Animate e.g. bird gliding possible.
C. Effort/control		
	i. Source	External to object but same as support AIR.
		Autonomous movement excluded, FLY, WALK and the external agent being autonomous mover excluded e.g. THROW, ROLL, PUSH.
	ii. Requirement	No
		Yes impossible FALL excluded.
	iii. Control	None
		Controlled motion impossible. FLY and WALK excluded.
D. Original Stereotypes.		Grasp/Hold and Let go.

Figure X.5: Frame representation of the class of motion known as FALL

FRAME REPRESENTATION OF THE CLASS OF MOTION KNOWN AS FALL

SLOT	SUBSLOT	CONTENT
Header		FALL
Statement		A motion which takes place in the air in the downward direction. It occurs because there is nothing to stop it happening i.e. through "lack of prevention". (There is no adequate support present).
Features of the motion:		
A. Support		None
		Support impossible. CARRY, FLY, WALK, JUMP, THROW, ROLL, PUSH excluded.
B. Animacy		Inanimate.
		Animate possible.
		(The latter gives rise to distinctions between accidental and purposeful motion).
C. Effort/control		
	i. Source	Not required.
		Active effort (internal or external) impossible, CARRY, FLY, WALK, JUMP, THROW, ROLL, PUSH excluded.
	ii. Requirement	None
		Effort impossible, CARRY, FLY, WALK, JUMP, ROLL, PUSH excluded.
	iii. Control	None.
		Control impossible. FLY, WALK, excluded.
D. Original Stereotypes.		Let-go

Figure X.6: Frame representation of the class of motion known as ROLL

SLOT	SUBSLOT	CONTENT
Header		ROLL
Statement		The object has been set in motion by an external source and usually moves along the ground.
Features of the motion:		
A. Support		A solid - usually the ground.
		Possible: ice, or other solids. Above the ground such as on tables or shelves.
		Air EXCLUDED. FLY, JUMP, FLOAT, FALL, excluded.
B. Animacy		Inanimate.
		Animate possible.
C. Effort/control		
	i. Source	External autonomous agent satisfies conditions for WALK.
		FLY and JUMP excluded as motion on ground.
	ii. Requirement	Yes
		Lack of effort impossible, FLOAT and FALL excluded.
	iii. Control	None.
		Control impossible, FLY, WALK excluded.
D. Original Stereotypes.		Let go and move.

Figure X.7: Frame representation of the class of motion known as THROW

SLOT	SUBSLOT	CONTENT
Header		THROW
Statement		The object has been set in motion by an external agent and takes place in the upward direction in the air.
Features of the motion:		
A. Support		None
		Ground or in air support impossible, FLY, WALK, CARRY, PUSH, ROLL excluded.
B. Animacy		Inanimate.
		Animate possible but unusual.
C. Effort/control		
	i. Source	External agent.
		Own effort impossible, FLY, JUMP, WALK excluded.
	ii. Requirement	Yes
		No effort impossible, FALL, FLOAT excluded.
	iii. Control	None.
		Control impossible, FLY, WALK excluded.
D. Original Stereotypes.		Let go and move.

Figure X.8: Frame representation of the class of motion known as WALK

SLOT	SUBSLOT	CONTENT
Header		WALK
Statement		The motion is achieved on a solid support usually the ground by an autonomous source of motion.
Features of the motion:		
A. Support		Solid - usually the ground.
		Other solids above ground as long as they are strong enough are possible, e.g. floors of buildings.
		AIR impossible. FLY, FLOAT, FALL, THROW, JUMP excluded.
B. Animacy		Animate and Inanimate.
C. Effort /control		
	i. Source	Itself
		External agent impossible. THROW, ROLL, CARRY, PUSH excluded.
	ii. Requirement	Yes
		Lack of effort impossible. FALL and FLOAT excluded.
	iii. Control	Yes.
		Lack of control impossible. JUMP, THROW, ROLL, FALL, FLOAT, CARRY, PUSH excluded.
D. Original Stereotypes.		Self movement.

Figure X.9: Frame representation of the class of motion known as JUMP

SLOT	SUBSLOT	CONTENT
Header		JUMP
Statement		The object moves by itself i.e. up through its own effort into the air.
Features of the motion:		
A. Support		None.
		Support impossible. CARRY, PUSH, ROLL, FLY, WALK excluded.
B. Animacy		ANIMATE.
		Some inanimate possible e.g. Jack-in-box but exceptions.
C. Effort/control		
	i. Source	Itself
		External agent impossible. THROW, ROLL, CARRY, PUSH excluded.
	ii. Requirement	Yes
		No effort impossible, FALL and FLOAT excluded.
	iii. Control	None.
		Control impossible. FLY, WALK, excluded.
D. Original Stereotypes.		Self movement.

Figure X.10: Frame representation of the class of motion known as FLY

SLOT	SUBSLOT	CONTENT
Header		FLY
Statement		The motion is achieved in the air with the source of effort in the object itself.
Features of the motion:		
A. Support		Itself - (has recognisable agents of support).
		External solid support e.g. ground impossible.
		ROLL, PUSH excluded.
		Lack of recognised agents of support impossible, therefore JUMP, THROW, FLOAT, FALL, WALK excluded.
B. Animacy		Animate and inanimate.
C. Effort/control		
	i. Source	Itself
		External agent impossible. THROW, ROLL, PUSH, CARRY excluded.
	ii. Requirement	Yes
		Lack effort impossible. FALL, FLOAT excluded.
	iii. Control	Yes.
		Lack of control impossible. CARRY, PUSJ.H, FALL, FLOAT, JUMP, THROW, ROLL excluded.
D. Original Stereotypes.		Self movement/Hold

Figure X.11: Frame representation of the class of motion known as CARRY

SLOT	SUBSLOT	CONTENT
Header		CARRY
Statement		A carried object is one which inherits its support and motion from the same source.
Features of the motion:		
A. Support		This is provided by the source of motion, which has autonomous movement. Go to this frame. The source of support can only be selected from the WALK or FLY classes. (See its frame).
		PUSH, FLOAT, FALL, ROLL, THROW, JUMP are excluded sources of motion.
B. Animacy		The source of motion is usually a living thing for lighter objects.
		An inanimate source of motion is possible for heavier objects or for higher speed movement.
C. Effort/control		
	i. Source	Effort from another.
		Selected from WALK or FLY classes of motion.
		PUSH, FLOAT, FALL, ROLL, THROW, JUMP, are excluded sources.
	ii. Requirement	Yes
		No impossible, therefore FALL and FLOAT A excluded. FLOAT B is a possibility.
	iii. Control	The carried object has no control over its carried motion.
		Exception is the driver of a source of autonomous motion, e.g. car.
D. Original Stereotypes.		Grasp/Hold

APPENDIX XI

PUBLISHED PAPER

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My contribution to this paper is the empirical data, which I collected on separate occasions from two groups of secondary school pupils, (as described in chapter 5 and also found in unpublished M.Ed. report.)

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