Understanding and Use of Small-Scale Models as Representations of Large-Scale Spaces, in 3 to 6 Year Old Children: An Investigation of the Effects of Varying Task and Method.

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CONTENTS

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Declaration

I declare that the work undertaken and reported throughout this thesis was completed solely by the undersigned. This work has not been included in another thesis.

Victoria L. Perry

Publications

The following publications/conference presentations have been adapted from experimental work reported in this thesis:

Perry, V.L. & Campbell, R.N. (2000). Task variation and young children's understanding of a model of a familiar space. *Current Psychology of Cognition, 19,* 3, 307-332.

Perry, V.L. & Campbell, R.N. (1999). The development of young children's understanding of the relationship between a model and the room it represents. *Proceedings of the British Psychological Society, 8,* 1, 26.

Perry, V.L. & Campbell, R.N. (1998). The effect of task variation on young children's apparent understanding of the representational function of a model of an already familiar space. *Proceedings of the British Psychological Society, 7,* 2, 104.

"What do you consider to be the *largest* map that would be really useful?"

"About six inches to the mile."

"Only *six inches*!" exclaimed Mein Herr. "We very soon got to six *yards* to the mile. Then we tried a *hundred* yards to the mile. And then came the grandest idea of all! We actually made a map of the country on the scale of *a mile to the mile*!"

"Have you used it much?" I enquired.

"It has never been spread out, yet," said Mein Herr: "the farmers objected; they said it would cover the whole country and shut out the sunlight! So we now use the country itself, as its own map, and I assure you it does nearly as well."

(Lewis Carroll, 1893)

Abstract

Spatial representations are external, physical entities, which are used to symbolise real world environments. These kinds of symbols provide information about the world, and shape the way that we think about it. Previous research into children's understanding and use of spatial representations has led to differing conclusions about how and when such abilities develop. This may be due to the diversity of different tasks and methods which have been adopted in the past. The aim of this thesis was to provide a systematic investigation of some of these tasks and methods, in order to establish whether they assess the same underlying abilities, and whether children perform similarly on all such tasks, using all such methods. A series of studies compared performance on two tasks – positioning and retrieval – and on two methods – inferring from a representation to a referent space, and from a referent space to a representation. Error data and time data were recorded in addition to success and failure. Results show that when target locations are completely concealed, levels of absolute success are similar on the two tasks. However, children take more time on the retrieval task, which may indicate a difference in the way they approach tasks presented in a familiar game format. Results also show that the two methods may not be equivalent. Performance under these two methods differs in younger children particularly. Familiarity with the referent space leads to improved performance when inferring from referent to representation, and to more sophisticated response strategies overall. The presence of irrelevant material in either space does not affect performance. Results support the notion that some representational understanding can be achieved early in development, so representations of space can begin to be used

from three years of age. However, despite this early achievement of representational understanding, deficits in spatial cognition mean that the ability to fully understand and use spatial representations is still developing at 6 years of age.

Thesis Outline

This thesis explores the understanding and use of external representations of space by children, focusing particularly upon changes in children's performance due to the use of different tasks, methods of assessment, and experimental designs. The aim of this section is to provide a general overview of the purpose of each chapter.

Chapter One is a general introduction, providing a definition of spatial representations and an insight into their importance. It also serves to outline some of the theories of development in children, which allow for an understanding of how the understanding and use of spatial representations might develop.

Chapter Two provides a detailed review of some of the tasks and methods which have previously been used in this domain, to assess children's understanding and use of spatial representations. Traditionally, research in this area tends to use a real world environment as a referent space, and some representation of that space, and requires children to manipulate either the space or the representation in some way, in order to demonstrate their understanding of the relationship between the two. From this review it is clear that there are many possible representational media which have been used in different studies as well as a variety of different specific experimental tasks which children have been required to carry out. In addition, many aspects of these tasks have differed between studies – for example, whether the referent space used is familiar or unfamiliar, or whether it is a natural space or a contrived experimental space. This chapter suggests that because of the diversity of methods used in previous research, making judgements about children's abilities in this domain is difficult.

Performance is therefore the result of a trade-off between children's actual competence and the cognitive load of the particular experimental design employed. The chapter explains the overall aim of the project reported here, in explicitly addressing the issue of just how performance is affected by the use of different methods, tasks and by other experimental variables such as familiarity with the referent space.

Chapter Three outlines the general methodological approach adopted in all of the studies within the project. The method has been adapted from that used by Judy DeLoache since her original (1987) study in this area. Using this method, children view a room as the referent space, and they view a small-scale model of that room as the representation. They then view a target object hidden or placed at some location in one of the two spaces, and are required to themselves retrieve or position an analogous object from the analogous location in the other space. In this way, they demonstrate their understanding of the representational relationship between the model and the room, as well as their ability to identify correct spatial locations.

Chapter Four reports the first study carried out as part of this project, Experiment One, in which children complete the standard task with their own classroom as the referent space. This initial study aims to compare children's performance on two specific tasks – retrieval and positioning – and using two methods – inferring from Model-To-Room, or from Room-To-Model.

Chapter Five explores whether the children's familiarity with the referent space might have affected the pattern of performance in Chapter Four, and thus Experiment Two reported here replicates the previous experiment using a completely novel referent space.

Chapter Six presents Experiments 3A and 3B. Having explored a highly familiar referent space (Experiment One) and a completely novel referent space (Experiment Two), the studies in this chapter examine how performance changes when the level of familiarity with the referent environment, varies from slightly familiar to highly familiar.

Chapter Seven explores the effect of the quality of the representation itself. Experiments One, 3A and 3B use a fairly basic model, containing only structural elements of the referent room. However, Experiment Two uses a more detailed model containing soft furnishings as well as structural elements, and the colours of objects in the representation were truer to the colours in the referent space, to a much greater extent than was the case in Experiments One, 3A or 3B. Experiment Four therefore aims to compare performance using a basic model with that using a detailed model.

Chapter Eight examines the possibility that selective attentional capacities might be responsible for differences between Experiments One and Two, rather than the complete novelty of the referent space in Experiment Two. In Experiment One, the referent space is the children's own classroom, and therefore contains a great deal of irrelevant information in the form of additional material like toys and books. In Experiment Two, however, there is no additional material of this sort in the referent room. Therefore, it is suggested that children might be distracted by this additional material when inferring from model to room. Thus, this distraction might account for differences between Experiments One and Two, rather than the differences in the level of familiarity with the referent space. Experiments Five and Six reported here, explore children's performance when irrelevant material is present in the room, when it is not present at all, when it is present in the model, and when it is present in both model and room.

Chapter Nine provides a general discussion of the studies in the project. It summarises the main findings, and draws some conclusions regarding developmental issues. Based on the research presented within this thesis, this chapter suggests how children's performance on tasks designed to assess understanding and use of spatial representations is affected by the variations in task, method and other variables which were explored in this project. In addition, some suggestions for further research are made.

CHAPTER ONE

General Introduction

Definitions

The term "spatial representation" has several meanings. Firstly, it is applied to internal, mental spatial information about any real-world environment. Historically speaking, internal models of large-scale environments have been referred to differently, and also in different research domains. They have been called "imaginary maps" (Trowbridge, 1913), "mental maps" (Shemyakin, 1962), "environmental images" (Appleyard, 1969), "spatial images" (Boulding, 1956) and "spatial schema" (Lee, 1968). However, probably the most familiar term to psychologists is "cognitive maps". This type of terminology suggests pictures or maps, but in fact these internal models of space may not be maps, and may not even be map-like. As Siegel & White (1975) point out, they are often fragmented and distorted. It is also often the case that they are actually separate but connected models of smaller chunks of the whole environment.

However, the term "spatial representation" can also be used to refer to any external, physical, tangible entity, which is used to symbolise some real world environment. It is important to emphasise this distinction between internal and external spatial representations. Very often, it is assumed that an individual's internal spatial representation can be assessed through some task using an external representation of that environment (see Spencer, Blades and Morsley, 1989, Chapter One, for a review of such methodologies). Thus the two are undoubtedly related. However, the nature of internal representations, or "cognitive maps" is an issue of human spatial cognition, whilst an external representation is a physical entity. It is the aim of this thesis to examine the understanding and use of external spatial representations, and to investigate how manipulations of such external entities and their referents may affect this understanding. Such understanding may well rest upon cognitive abilities and this will be explored within the thesis, but it is the external representations which remain the prime focus throughout. Henceforth, the term "spatial representation" will be used to refer to external, physical representations of space. Where internal representations are the focus of discussion, this will be made explicit.

The importance of spatial representations

The emergence of the ability to use symbols in general is an important stage in many theories of cognitive development (e.g. Werner & Kaplan, 1969; Piaget & Inhelder, 1969). The ability to use language marks an important stage in any child's development. But symbolic functioning is also evident when a child, for example, turns a cup upside down and uses it as a hat. This represents a significant stage in development because the child understands that the object is a thing-in-itself, but that it can also be used to represent something else. DeLoache (1993) calls this "One of the foremost achievements of early human development." She goes on to explain,

"Children come to realise that a variety of culturally defined symbol systems represent or stand for other objects, events, or ideas. They learn

that pictures, numbers, and maps have referents, that they stand for something other than themselves." (p91)

DeLoache and Burns (1994) expand upon this, and explain just why this type of understanding is so important, although in the first sentence of this quote they may have overstated their point.

"Our capacity for the creative and flexible use of symbols is what sets us apart from other species. In modern, industrial societies, there are many symbol systems that must be mastered for full participation in society. We must speak fluently and use gestures comprehensible to others. We must be able to count and do math, to read and to write." (p513)

Maps and models are also types of symbols, but instead of representing objects, they represent space. These types of symbols are of particular importance because they provide us with information about the world, but also because they influence the way that we think about the world, and are culturally defined in the same way that other symbol systems are (see Gauvain, 1993, for a full discussion of the socio-cultural aspects of spatial thought).

Siegel & White (1975) explain that any type of spatial knowledge is essentially encoded in symbols, and these symbols are affected by the conventions of the individual's particular society or culture. In several studies of Inuktitut (Eskimo) spatial deictics, Peter Denny (1978; 1982) explores the fact that different cultures have very different words to describe spatial concepts, and that this leads to very different ways of thinking about space. For example, he suggests that in Westernised cultures non-deictic locatives such as "down-the-road" or "round-the-corner" can be used to adequately relate space to human actions. However, natural environments such as the Arctic tundra, have not been shaped to facilitate human action, and therefore one way to relate the space to human activity is to use deictic spatial concepts which centre space on the speaker. In English, the two words "here" and "there" make up the spatial deictic system, contrasting the speaker's location with all other possible locations. In Eskimo, however, the spatial deictic system comprises 88 words which, Denny argues, enable Eskimos to think about spatial locations in very different ways to English speakers.

Siegel and White (1975) describe a race of people for whom the sea is particularly important, and which therefore forms a central part of their system of spatial referencing. This is evident from one anecdote in which a member of this society was heard telling another that "..you have mud on your seaward cheek.." (p16) As Siegel & White point out,

> *"Being a social animal and developing within a social context, man construes reality in the terminology of his culture. Part of this reality is symbolised space." (p16)*

Spatial representations also provide us with information about the world which we would otherwise not have access to. We are able to learn about places we have never visited, and to have a conception of where certain landmarks, cities and countries are in relation to others. One example, of satellite images of Earth, demonstrates clearly how representations provide us with information that we otherwise could not possibly hope to have (Liben, 1997).

In addition, spatial representations are important because they influence the way we think about the world, and the way in which we visualise it. It is therefore important that we investigate how young children understand spatial representations in order to gain an insight into how they can think about the world. Blades and Cooke (1994) explain the importance of this type of understanding.

> *"Understanding an external representation is an important developmental achievement, one that has implications not only for theories of spatial abilities per se, but also for several other aspects of development. For example, children's recognition that a representation provides a particular view of the world is one facet of perspective taking...; their ability to select information from a map or a model and apply that information to the represented environment can be considered in the context of early analogical reasoning...; and children's use of external representations is an example of learning from culturally mediated symbolic tools.." (p202)*

Similarly, Blades and Spencer (1994) comment that,

> *"Spatial representations are an important and common aspect of most cultures- they both provide information about the world and influence the way that people think about and visualise the world....and with the rapid development of computer based Geographical Information Systems it is*

likely that spatial representations will become even more important, for both professional and non-specialist users.." (p4)

Recent research, then, has investigated young children's developing understanding and use of spatial representations as abilities in their own right, as well as for what they can add to our understanding of the development of spatial cognition in general.

Theories of spatial development

Various theories of spatial development have been suggested over the years. This section will explore some of these theories and how each of them aims to explain children's developing understanding of spatial representations.

Piagetian theory

In terms of explaining Piaget's theory of the development of the concept of space in the child, it is first necessary to explain the important distinction which he makes between perceptual space and cognitive space (Piaget & Inhelder, 1956: p3). Perceptual space is, in Piaget's view, concerned with the more figurative aspects of knowledge, whilst cognitive space is concerned with the operative aspects of knowledge. According to Piaget, knowledge of any sort must include these two aspects, since to know any object is to construct or reconstruct it. The essentially operative aspect is related to the actions or the operations by which the subject submits the object to the transformations necessary for its reconstruction. Thus, it is dependent upon intelligence. The figurative aspect relates to the perception (direct or pictorial) of the successive states or momentary configurations between which the transformational activities must intervene. Thus, it is dependent upon perception or the mental image.

Piaget stresses that intelligence does not arise out of perception, but rather that a reciprocal influence or functional interaction must operate between the two. The information which comes from perception or the mental image is the raw material for the intellectual action. Yet reciprocally these intellectual activities have an influence upon perception (either directly or indirectly), thus enriching and increasing the flexibility of its functioning with development. In this way, intelligence remains distinct from perception, yet the two remain related aspects of knowledge and reality. Their development can be complementary, but often in very different directions. In Piaget's works he indicates that the perception of space, as opposed to the conception of space, is always essentially relativistic in character. It is never really free from systematic distortions, because of the irreversible nature of the perceptual structures.

The development of sensori-motor space, according to Piaget, occurs during the first two years of childhood, and is one of the major achievements of sensori-motor intelligence. The actions of the child and their displacements, which involve both their perceptual functions and their motor functions, lead to a progressive structuring of space through increasingly complex co-ordinations. In this way sensori-motor space clearly involves more than just mere perception, and depends greatly upon the intelligent or operative aspects of knowledge. Piaget describes this sensori-motor space as a space which is practical, experienced, organised and balanced, at the level of action or behaviour. Nevertheless, at this early stage in development, the absence of the symbolic function means that the child is unable to imagine this space, or to mentally reconstruct it. However, these perceptual sensori-motor structures form the foundation of the construction of representational space (p5).

With the advent of the symbolic function in the child, at about the age of two years, representational space begins to develop. This is more than just an internalisation or image reproduction of sensori-motor space (p3). Spatial representation is added to and derives from sensori-motor space, and enables the child to act upon objects which are symbolised or mentally represented, as well as those which are physically present. It develops progressively, and involves a long period of internalisation, from action to operation.

From geometry, Piaget identifies three main types of geometrical relations, and he traces their development in children. The most basic relation in developmental terms, is topological space. This depends purely upon the qualitative relations which are inherent in a particular figure, such as nearness or proximity, separation, order or spatial succession, and enclosure or surrounding. Thus topological space is restricted to the internal properties of particular objects, and allows only for analyses which operate from the standpoint of each figural object in isolation (p153). This is followed by projective space and Euclidean space.

> *"With projective and Euclidean space we encounter a new and different problem, that of locating objects and their configurations relative to one another, in accordance with general perspective or projective systems, or according to co-ordinate axes. Projective or Euclidean structures are therefore more complex in organisation and are only evolved at a later stage in the child's development." (p153)*

In projective space the concept of the straight line serves as the basis for spatial relationships. Thus projective space is concerned with the relation of one object to others, but from a particular perspective or point of view (p154). The final stage in development comes with the advent of Euclidean space, which is based mainly upon the concept of distance. The child is able to locate an object in terms of a system of axes or co-ordinates. Euclidean and projective space both derive from topological space, but are then constructed parallel to one another. Though distinct from one another, they nevertheless remain closely related.

In terms of the development of understanding of external representations of space, Piaget actually had very little to say, since he believed that any understanding of external representations of space was derived from an already established internal representation of space. However, Piaget & Inhelder (1956) did some very early research using two identical models, one of which was to serve as a representation of the other. A doll was positioned on one of the models, and the child had to position another doll at the equivalent position on the second model.

Stage I children (ages 3.0-4.0 years) appeared only to be able to focus upon one aspect of the doll's position in the first model. Piaget's explanation for this behaviour was to say that these children relied upon simple topological concepts, i.e. that the child just thought of the doll as being "in" a particular area, or "near" a particular object. So, if the doll was in a field on the first model then the child might place the second doll in a field on the second model, but would not attend to *which* particular field by noting, for example, which other objects it was near to.

In Stage II, children began to position the doll in relation to two or three features, and then after the ages of seven or eight, the children were always successful. Thus, in Piaget's view, children's failure to understand spatial representations can be seen as a result of their reliance upon simple topological concepts.

In another task children viewed a model village and were then presented with a set of identical objects which they were to use to construct a replica of the original model. These objects were either of the same scale as the original model, or of a smaller scale. Children were presented with either the same number of objects as were in the original or more, in which case the child would have to choose between the available objects and select the correct ones to use (Holloway, 1967).

In Stage I children were able to achieve neither spatial correspondence between the sets of objects, nor one to one correspondence. Sometimes certain proximities may have been observed, but usually objects were either bunched together, or put in a line in a different order to that which they assume in the original. By seven or eight years children were able to copy the model perfectly, apart from precise measurements and reductions to scale. Performance therefore improves as they progress through reliance upon projective and finally Euclidean concepts, and the ability to understand and to use a representation of space would be a late developing skill, emerging at around seven years of age.

In addition, Piaget and Inhelder's (1956) well-documented "three mountains" task suggests that until nine or ten years of age, children have difficulties appreciating perspectives other than their own. Children were shown a model of three mountains and were asked how it would look to an observer situated at a different location. The children responded by building a model, or by selecting a picture which showed the mountains from various perspectives. Until nine or ten years, children tended to respond by selecting the view which showed the mountains from their own perspective.

External representations of space tend to show the referent environment from a different perspective to that which a child is likely to encounter. Thus, Piaget's views about perspective, coupled with his account of the development of the concept of space, seem to suggest that we should expect the ability to understand and to use spatial representations to be a late developing one.

Perhaps because of this Piagetian framework, young children's abilities in understanding and using representations of space, were overlooked by researchers until more recently. Liben (1982) explores some alternatives to the traditional Piagetian tasks used in assessing spatial cognition generally, which other researchers have employed. She advocates caution in drawing conclusions from Piagetian methods, since children's actual spatial competencies may not be adequately reflected by their performance on such tasks. In addition, the findings of more recent studies indicate that the ability to understand and use spatial representations specifically, may not be as late to develop as Piaget's theory suggests. Mark Blades in the UK and Judy DeLoache in the US have separately been at the forefront of research within this domain, carrying out many different studies aimed at exploring young children's understanding and use of spatial representations, and their research suggests this to be a much earlier developing skill than had previously been thought.

DeLoache's theory

DeLoache (1995a; 1995b) proposes a model of young children's symbol understanding and use, which is based on her extensive research into children's understanding and use of small-scale models. However, she explains that she intends the model to apply to a broad range of different symbol types, apart from just models, and not restricted to representations of space. This model is a revision and extension of the model posited previously in DeLoache (1990), and is shown in Figure 1.

DeLoache's model can be seen to be similar to Gentner's (1983;1989) theory of analogical reasoning, which outlines the development of the ability to recognise that a set of related items have some relationship to another set of related items, though Gentner did not focus upon relationships between representations of space and their referents specifically.

In DeLoache's model, the behaviour which represents the output is the appropriate use of a symbol. DeLoache bases her model on research using her typical experimental paradigm. Children view a room as the referent space, and a small-scale model of that room as the representation. A target toy is hidden at some location in the model, and children are asked to retrieve a previously hidden analogous toy from the equivalent location in the room itself (or vice-versa). In the research upon which DeLoache bases her model, the behaviour which represents the output would constitute retrieval of the previously hidden object, from either the small-scale model, or from the referent room.

Immediately underpinning the ability to make appropriate use of a symbol in this model, is the ability to map the elements of the referent to those of the symbol, or vice-versa. This Mapping ability is therefore bi-directional.

Underpinning the ability to map in this way, is the central component of the model – a higher-order appreciation of the relationship between the symbol and its referent, which DeLoache terms "representational insight".

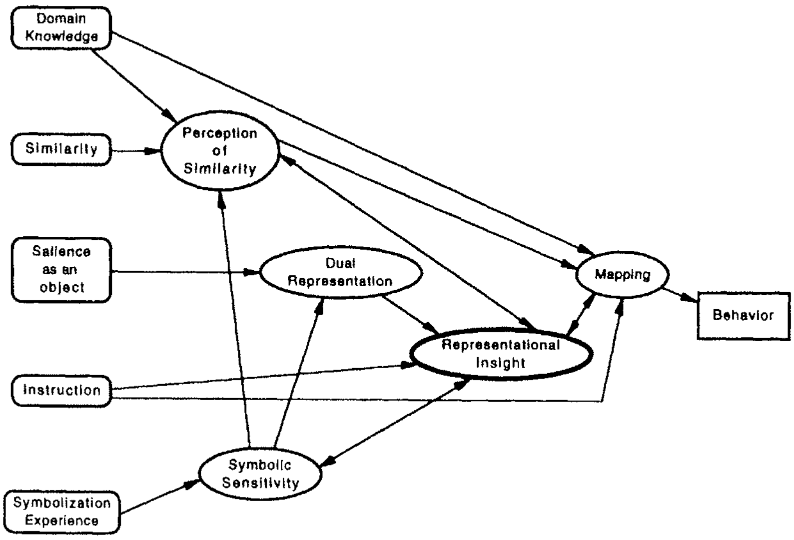

Figure 1. DeLoache's model of symbol understanding and use. (Taken from DeLoache, 1995).

In the model, representational insight is facilitated by a combination of multiple factors. The first of these is "Instruction". In the majority of DeLoache's studies, she employs an extensive orientation phase prior to commencing testing. However, when this instruction phase is modified to provide less instruction to children, they perform more poorly. DeLoache emphasises that this fits with Gentner's (1983) theory of analogical reasoning, since in her terms instruction ought to foster "structural alignment" between the symbol and the referent, by encouraging children to compare their mental representations of the