

# **Children's Handling of Ambiguous Input**

**by**

**Sarah Ruth Beck**

A thesis submitted to  
the University of Birmingham  
for the degree of  
DOCTOR OF PHILOSOPHY

School of Psychology  
The University of Birmingham  
November 2001

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BIRMINGHAM

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## Contents

<b>Chapter 1 Introduction .....</b>	<b>1</b>
1 Basic difficulties with ambiguous input .....	2
2 Other approaches to difficulties with ambiguity: Interpretative Theory of Mind and Logical Reasoning and Undecidability .....	17
3 Strategies .....	24
4 A functional application of executive function .....	37
5 Introduction to Experimental Work.....	48
<b>Chapter 2: Are Children’s Interpretations of Ambiguous Messages Tentative? .....</b>	<b>54</b>
1 Experiment 1: A comparison of children’s willingness to revise their interpretations with their knowledge evaluations.....	55
2 Experiment 2: Are children’s reinterpretations of ambiguous messages revisions or restarts? .....	65
3 Experiment 3: Can children seek information to increase the accuracy of an interpretation? The Cones Procedure. ....	71
4 Discussion of Experiments 1-3 and Summary .....	77
<b>Chapter 3: The Possibility of Performance Errors .....</b>	<b>81</b>
1 Experiment 4: Resolving ambiguity in stories with hindsight .....	83
2 Experiment 5: Does personal involvement improve performance on a counterfactual ambiguity task? .....	88
3 Discussion of Experiments 4 and 5 and Summary .....	95

<b>Chapter 4: Knowing When You Know .....</b>	<b>98</b>
1 Introduction: A move from strategy selection.....	98
2 Experiment 6: Knowing when you know and the effect of risk.....	102
3 Experiment 7: Is the stop game easier than the cones game?.....	112
4 Discussion of Experiments 6 and 7 and Summary .....	123
<b>Chapter 5 Identifying Disambiguating Information .....</b>	<b>127</b>
1 Introduction .....	127
2 Experiment 8 Useless clues .....	128
3 Discussion of Experiment 8 and Summary .....	139
<b>General Discussion and Future Work .....</b>	<b>144</b>
1 Summary.....	144
2 Future Work.....	159
<b>Appendix A: The probability of answering at chance on experimental procedures.....</b>	<b>166</b>
1 Cones Procedure.....	166
2 Stop Procedure.....	168
<b>Appendix B: Stories used in Experiment 4 .....</b>	<b>169</b>
<b>References .....</b>	<b>174</b>

## List of Tables

Table 1: Trials used in Experiment 1.....	59
Table 2: Mean number of appropriate responses in Experiment 1.....	62
Table 3: Trials used in Experiment 2.....	67
Table 4: Frequency of looking under cones in Experiment 3.....	74
Table 5: Mean responses (scores between 0 and 2, scored for tendency to say "ask").....	86
Table 6: Performance on ambiguous trials in Experiment 5.....	92
Table 7: Comparison of overall strategy use between Experiment 3 and Experiment 5.....	94
Table 8: Responses in stop game by trial on Experiment 6.....	106
Table 9: Chi Square tests to compare performance between trials in Experiment 6.....	107
Table 10: Mean scores on cones game by cone order and game order.....	114
Table 11: Responses in stop game by trial on Experiment 7.....	115
Table 12: Chi Square test results comparing discrimination between trials.....	115
Table 13: Comparison of probabilities for measures of success in stop and cones game.....	118
Table 14: Picture sets for clues game.....	132
Table 15: Comparison between performance on narrowing and useless trials.....	135
Table 16: Performance on trial immediately following feedback.....	136
Table 17: Clues tasks compared to adjusted cones strategy.....	138

## List of Figures

Figure 1: Probability tree for cones game .....	166
Figure 2: Probability tree for stop game .....	168

## **Abstract**

I explored young children's abilities to use behavioural strategies to handle ambiguity, and whether two subcomponent skills, monitoring (un)certainty and identifying disambiguating information, caused them difficulty.

Despite success revising interpretations based on ambiguous input (Experiments 1 and 2), 5- to 6- year old children failed to seek disambiguating information appropriately (Experiment 3). Although children treated their interpretations as if they were tentative, their failure to perform a simple seeking response suggested that they did not know they were tentative at the time of making them. Their difficulties were unlikely to result from an inability to resist making an immediate interpretation, as they were unable to select appropriate strategies with hindsight (Experiments 4 and 5).

Children performed relatively well when they had only to monitor their (un)certainty (Experiments 6 and 7). However, they did not choose disambiguating information in preference to ambiguous information that narrowed their choice of referents (Experiment 8).

I argue that although children experience uncertainty when confronted by ambiguity, they are unable to plan what to do to remove it. Until the age of around 7, children do not know why ambiguous input gives rise to uncertainty and hence, cannot select appropriate strategies to resolve the problem.

## **Acknowledgements**

I would like to thank Liz Robinson, who has provided me with excellent supervision, guidance and generous understanding throughout my research.

I have very much enjoyed working with the staff and postgrads of the Psychology Department at the University of Birmingham. The members of the developmental research group provided stimulating and encouraging discussion, and Ian Apperly and Emma Whitcombe, with whom I worked most closely, thrashed out various methodological and theoretical difficulties with me over our working lunches.

This project was funded by the Economic and Social Research Council and, of course, the empirical work would not have been possible without the cooperation of the staff and children of the schools where I tested: King David, Lakey Lane, Park Hill, Wheeler's Lane, St. John & St Monica's and Billesley Schools in Birmingham and Farley Hill School in Reading.

The support of many people both in Birmingham and beyond has been vital during my research. I would especially like to thank all those who provided understanding and entertainment throughout. In particular, Ian who, when excused from conversations about my research, provided social support for which I will always be grateful; Martin Holt was emotionally dependable and tirelessly challenged my positivist stance; my other housemates: Nina Booth-Clibborn, Greg Bruce (for table 13), Farouk Soussa, Arnaud Chevalier and Dan Carroll; and (from their own homes) Laura Davison, Laura Shapiro and Adam Cooper survived various stages of my research and all kept me on the straight and narrow.

As well as my current housemates, Gareth Treharne and Chris Higgins are much appreciated for proof reading chapters of my thesis.

Finally, my parents and my sister, Katy, have been wonderful. They have given me endless care and support (both emotional and financial) and I am extremely grateful for their encouragement.



## Chapter 1 Introduction

In everyday life we frequently encounter information which leaves us uncertain as to its correct interpretation. It might be a partial view of an object, a word that has more than one meaning, a sentence that has different interpretations. In one sense all input that we receive could logically be thought of as ambiguous: in an extreme example, we look out of the window and see the view but this could be a perfect picture of the outside world, which we mistake for reality. We hear someone say “hello” and assume they are speaking in English, but they might be saying a word from a language utterly alien to us, in which this word sounds the same, but has a completely different meaning. These extreme examples of ambiguity are not the concern of this thesis and the uncertainty inherent in our perceptual experiences are better left to the Empiricist philosophers. Rather, in this thesis I explore what people, specifically young children, do with information that is more immediately ambiguous.

This ambiguous information, with which I am concerned, comes in many different forms. In a simple example you might imagine someone asking you to pass them their coat, but turn to see several coats hanging up. The request is ambiguous in that there is more than one potential referent for the message, yet only one is intended (in contrast to an indeterminate problem, which does not have a single intended referent (see this chapter, Section 2.2)). Thinking about possible actions in this situation introduces the methods of handling ambiguity I will explore in this thesis. If the person was nearby you might take the nearest coat and ask “This one?” assuming that if you are wrong then s/he will correct you. In this situation making a tentative interpretation and acting on it, while being prepared for corrective feedback, is an effective response. Furthermore, you might draw on your background knowledge to make this tentative guess (for example, you might know that the

person likes a particular colour or style and take the coat that fits with this). Alternatively, you might decide that you need further information before being able to make an interpretation. You might seek this disambiguating information actively, asking “Which one is it?” or you might hold the different interpretations in mind, but passively await extra information. This delaying tactic might be used by adults in situations of high risk where it is dangerous to make a guess, but there is no immediately available source of information.

Such strategies are sensible ways of handling ambiguity, albeit in different circumstances. Consider now a different way of responding to the message about the coat. You see several coats hanging up, take one and despite noticing that there are other potential referents of the message, you hand it to your friend as if it is certainly his/hers. This response, to make a confident not a tentative interpretation, is inappropriate given the ambiguous nature of the input you received. Yet it is this type of response, choosing a referent without seeking further information, nor acknowledging that another coat may have been the intended one, that has resulted in the claim that until the age of about 7 children do not understand how to handle ambiguous input. In order to see how this claim has come about, I turn to the literature on children’s understanding of ambiguity.

## 1 Basic difficulties with ambiguous input

### 1.1 Non-verbal Behaviour

What do young children do in response to ambiguity? Several studies have found that, between the ages of about 5 and 7, children’s responses do differentiate between ambiguous and informative messages. Plumert gave children messages about the location of a target object in a doll’s house (Plumert, 1996). Children were given the choice of asking further questions about the target’s location or finding the target immediately and their behaviour

was videoed. Five year olds showed significantly longer search latencies (that is, there was a longer time between hearing the message and touching an object) when messages were ambiguous rather than informative. These 5 year olds appeared to identify problems with the ambiguous messages. Plumert suggests that only problem detection skills can be attributed to children of this age, as they rarely asked questions of the experimenter to disambiguate ambiguous messages.

The performance of even younger children is less clear. Plumert found no difference in 3 year olds' search latencies following ambiguous and informative messages, after she had controlled for the complexity of the language used. (In early experiments the young children took longer to respond to informative rather than ambiguous messages, but this appears to be a result of the more complex language used in the informative messages e.g. "It's in one of the bags" compared to "It's in the bag next to the hat".) In Plumert's study the younger children appeared not to detect problems with the ambiguous messages. This is in contrast to Baldwin's findings (Baldwin, 2000) that infants (12-13 months) were more likely to look to an adult speaker who said a new name, when there were two objects in front of the child, than when there was only one, i.e. when the message (the new name) was ambiguous. In another study (Moses, Baldwin, Rosicky, & Tidball, 2001), 12 month old infants who were shown two new toys, looked to the adult when she made an emotional exclamation, while the child was engaged with one of the toys. The child did not simply associate the adult's emotion with the toy they were looking at, but appeared to find out which of the toys the adult was looking at. At first glance it may seem that these very young children were seeking disambiguating information from the speaker, to clarify to which of the two objects the speaker was referring. However, a more simple explanation is that the infant has detected a problem and so looks up, but with no understanding of what information is needed to resolve the problem, and

indeed without understanding of what the problem actually is. Results to be presented later in this thesis suggest that even at the age of 6 children can perform a seeking response without genuine understanding of what is problematic about ambiguous information (Experiment 3).

Whether or not the very young children detected a problem when they encountered ambiguity, Plumert's results show that the 5 year olds did. This is supported by other studies of young children's responses to ambiguity. Patterson, Cosgrove and O'Brien also analysed videos of children who heard ambiguous and informative messages (Patterson, Cosgrove, & O'Brien, 1980). There were four age groups, mean ages 4 years 4 months; 6 years; 8 years 1 month; and 10 years. Data from the pretest, that is without any encouragement to ask questions, showed a significant effect of message type on all four of the non-verbal measures they used (response time, eye contact, body movement and hand movement). Analysis of the non-verbal behaviours produced by different age groups found that the 4 year olds showed significantly different levels of eye contact to ambiguous and informative messages. Reaction time and hand movement were also sensitive to message type, although not significantly different. There was also a significant effect of message type on non-verbal behaviour for older children. The 6- and 8- year olds showed longer reaction times, greater body movement and greater hand movement in response to ambiguous than informative messages (the 10 year olds were so good at question asking that their non-verbal behaviour was not considered by the authors). The authors were also concerned with the relationship between non-verbal and verbal responses and the results from post-test trials suggest that verbal responding (asking questions) does not replace non-verbal responses as the latter were similar both when questions were and were not asked. Patterson et al argue that these non-verbal measures could be 'particularly sensitive measures of the early emergence of comprehension monitoring' (p47). This raises the issue of comprehension monitoring and whether it is

possible for children to monitor their comprehension accurately, but only be able to reveal this through non-verbal but not verbal responses. It might be that the child is unable to employ the strategies deemed by the experimenters to be appropriate (as discussed in Section 3 of this chapter). In my work I will explore new procedures which offer the child very easy strategies to respond to ambiguity and remove the verbal demands common to many tasks. The distinction between problem detection and understanding what one should do to respond will be important in my analysis.

## **1.2 Simple Linguistic Tasks**

Despite the problem detection behaviours seen on the above tasks, young children are generally regarded as having great difficulty with ambiguity. Work in this area has tended to focus on linguistic ambiguity. In two early studies, which used relatively abstract tasks, children failed to show understanding that individual words can be ambiguous.

In Asher's work (1976) children generated and evaluated single word clues, which were intended to identify one of a pair of words. For example, 'roar' would be a good clue to identify lion from the pair lion-sheep and 'animals' a poor clue to identify kittens from the pair kittens-dogs. An age effect was identified with older children producing and evaluating clues more effectively. As the youngest children in this experiment were 2nd graders (7- to 8-year olds), the oldest 6th grade (11- to 12- year olds), we see that even children older than 7 had difficulty understanding the communicative value of ambiguous (poor) clues. This poor performance by children at an age when they perform quite well on other ambiguity tasks (the message and knowledge evaluation tasks, described in sections 1.3 and 1.4, for example) suggests that such explicit evaluation tasks may have added demands, over and above the ability to deal with ambiguity using some effective strategies.

Bearison and Levey (1977) improved on Asher's work, arguing that presenting children with single word clues 'eliminated most of the contextual features that commonly define communicative contexts' (p717). In their study they gave children sentences with ambiguous pronouns or nouns and asked them to evaluate them. An example message is 'Jane got a bicycle for Christmas and Mary got a new coat. What did Jane (unambiguous message)/ she (ambiguous message) get for Christmas, a bicycle or a new coat?' As in several studies of ambiguity, the evaluation responses required were asymmetrical: children were asked to answer the question if it was a good one, but tell the experimenter if it was a bad question and explain why. This asymmetry of responses is a methodological problem I have tried to avoid in my procedures. In Bearison and Levey's study children's response latencies were measured and their evaluations compared. Children from three age groups were tested: kindergarten (5- and 6- year olds), 2<sup>nd</sup> grade (7- and 8- year olds) and 4<sup>th</sup> grade (10 year olds) participated in this study. With regard to response latencies, the younger children were slower to respond and responses to ambiguous messages were slower in general. On the evaluation test, children appeared to perform well when evaluating good messages, but differences were seen with age for ambiguous messages. However, the poor performance seen on ambiguous trials, should raise suspicions about whether performance on the informative trials was really good. This apparently good evaluation of informative messages might be the result of a bias to overconfidence or a response bias (among other possibilities). I consider children's success in responding to sufficient information in Chapter 4. Interestingly, when the youngest children in this study were categorised as poor (who evaluated 0 or 1 ambiguous trials correctly out of 6), transitional (scored 2-4) or good decoders (scored 5 or 6), the transitional group showed longer latencies than the other groups. This is inconsistent with the claim, made by Patterson et al (1980) above, that the latency

measure is a sensitive measure of communicative comprehension, instead this result suggests longer latencies are shown by children who are beginning to understand about ambiguity, deliberating over the uncertainty they feel about the appropriate response.

### **1.3 Knowledge evaluation**

An obvious limitation of these simple linguistic evaluation tasks is their abstract nature. Children's difficulties with ambiguity are interesting to developmental psychologists because responding to ambiguity is something which causes so few problems for adults in everyday life. However, in the real world, one is rarely called on to evaluate input out of context. A different approach to children's understanding is employed in message based tasks, in which children hear a message that potentially refers to one or more items in an array. In these communication games the speaker has a goal: to identify one of the referents, and so in these tasks, the child needs to think about the success or failure of a message in context. In terms of investigating what children understand about ambiguity this is an advance, yet difficulties remain with this research, which have been the starting point for my work. There is an over reliance on explicit verbal measures to test children's understanding, their understanding of ambiguity is often investigated only within the context of their understanding of the communication process and the strategies available to the child are limited. As I noted at the beginning of this introduction, the strategies employed by adults are varied and so generalisations based on children's performance using only certain strategies might be unfounded.

Robinson and Mitchell (1990) showed children sets of familiar and unfamiliar cartoon characters and asked them to identify the X (e.g. He Man (a well known children's character) or Murkor (an invented name)). Children were told, "One of these people is He Man/Murkor. Which one of them do you think might be He Man/Murkor?" Children then judged whether

they “knew” that they had chosen the correct picture. Robinson and Mitchell also investigated alternative wordings to “know” or “don’t know”, so some children judged “know” compared to “just think” and some children rated the trials as “easy” or “hard” ones. Children’s difficulties with the undecidable response (saying “don’t really know” or “just think” etc.) was not a superficial one, based on the wording of the question nor was it the result of the child using “know” to express desire rather than knowledge. Furthermore, reducing the ‘face saving’ element of the task (by delaying when the child was shown whether s/he was correct and having the experimenter feign forgetfulness about which picture the child chose) did not improve performance. However, children were better at acknowledging ignorance when they were asked a “Have you ever heard of...?” question without being asked to choose from a set of pictures. In this final task the child is asked only to evaluate his/her current state of knowledge or ignorance. They are not dealing with an ambiguous message which might or might not lead them to their goal of identifying the referent. When children were asked this question before a standard message evaluation task (in which there was a set of potential referents) their performance improved. Robinson and Mitchell (1994) suggested that children have particular difficulty with performance based knowledge judgements, those where the child is trying to act on an ambiguous (or informative) message. Consistent with this, it might be that children in the original study (1990), were aided by the first “Have you ever heard of...?” question because it helps them to direct their attention to feelings of uncertainty, rather than their ability to respond to the message by choosing a referent. In my experiments, I further explore to what degree children might be able to respond appropriately to ambiguous messages, when the demands of explicit evaluation are removed.



#### **1.4 Message Evaluation**

As we have seen in the previous section, children have difficulty evaluating knowledge and might be answering the question by evaluating whether or not they can respond to the message, rather than focusing on their actual state of knowledge. To increase our understanding of why children might make these misjudgements, I now turn to a second type of evaluation task: those in which the child is asked to judge the quality of the message itself, rather than the knowledge they have based on it. Whilst this is a move away from the question of whether children can react to ambiguous information by using an appropriate strategy, this literature adds to the weight of the claim that children have genuine problems with ambiguous input and shows serious problems in their ability to identify inadequate messages.

Meissner (1978) used a task in which children heard ambiguous messages about an array of toys. As in Bearison and Levey's task the responses required were asymmetric – if a message was good children were to respond to it by identifying the toy, if bad they had to resist responding, describe it as such and explain why. Older children (7- and 8- year olds) outperformed younger children (5- and 6- year olds) and performance on good message trials was better than bad. The most interesting finding was that although older children showed little difference in their success on good and bad messages, the younger children had a particular problem evaluating the bad messages. Unfortunately, the paper does not give us sufficient information about the younger children's errors to know if they were making interpretations (as other studies might lead us to expect) or whether they resisted making an interpretation but failed to justify it. An aim of my work has been to develop a more detailed analysis of what children do in response to ambiguous messages.

In a later task (Sodian, 1988) 4 and 6 year old children evaluated knowledge based on ambiguous messages. The younger children performed significantly worse than the older when they shared the speaker's perspective, i.e. when they knew the actual target location. Although a similar age difference was not significant for the listener perspective, the trend was in the same direction, and Sodian suggests this lack of significance may be the result of a small sample size. She claims that younger children may be able to judge knowledge based on a feeling of uncertainty without understanding the consequences of ambiguous information for knowledge. In a second task, performance on a knowledge evaluation task was compared with that on a message evaluation task. In the latter children answered "Did X tell Y exactly where the chocolate is or did she not tell her exactly where the chocolate is?" 5- to 6- year olds showed no difference in performance on speaker and listener perspective trials, but their performance was poorer when they had to evaluate the message rather than knowledge. Overall, Sodian's findings indicate that understanding of ambiguity is not a simple skill, but responding to these types of tasks require different abilities in combination – an understanding of the circumstances which will and will not lead to knowledge and the ability to recognise the role of the message itself in providing information.

Singer and Flavell (1981) investigated understanding of the message specifically, asking children to rate messages as "very clear", "just so-so" or "not clear". Children observed a puppet acting on messages. When the message was ambiguous, the puppet identified the two potential targets and either said "I think she means this one" or "I cannot pick one. I do not know which one she means". The older children (7- and 8- year olds) evaluated the messages correctly. They rated informative messages as more clear than ambiguous ones and did not differentiate between ambiguous trials on which the puppet made confident or less confident statements. The younger (5- and 6- year olds) children's

ratings were influenced by the puppet's response, and even though they generally rated informative messages as more clear than ambiguous ones, there were fewer children in the younger group who showed a 'mature' pattern of responding. Although the authors interpret this finding as showing that young children have an 'unconsolidated and unstable' (but not nonexistent) understanding of ambiguity, it may also have arisen from children not paying any attention to the quality of the message, but basing their evaluation of the message solely on the puppet's behaviour. This suggestion is supported by Robinson and Whittaker, who report similar results.

In this study (Robinson & Whittaker, 1986) 5- and 6- year old children watched two characters play a communication game in which the speaker would choose a target toy from a set and give a message about it to a listener. Messages were either ambiguous or informative and took the form "I've chosen one and he's got a yellow hat". The child was asked to evaluate the message by judging whether or not the speaker had said enough. Very few children (21%) accurately evaluated the message quality. 45% of the children judged that the speaker had said enough regardless of the quality of the message. In this study, as in Singer and Flavell's, the listener acted on the message and children's evaluation of the message appears to have been influenced by this performance: 34% of children evaluated informative messages as inadequate when the listener made an incorrect choice. Interestingly, children did not only overestimate the knowledge to be gained from ambiguous messages, but some children were also poor evaluators of informative messages (c.f. Patterson & Kister, 1981).

Robinson and Robinson (1977a) explored the communication process further asking children to explain communication success or failure and attribute blame following failure. Younger children (5- and 6- year olds) were more likely than older (7- and 8- year olds) to blame the listener when the message was ambiguous and s/he made an incorrect

interpretation. A second study found a similar age difference in performance, when children watched two dolls play a communication game (Robinson & Robinson, 1977b).

Children also have difficulty understanding why communication failure occurs when they are trying to achieve a more elaborate goal. Flavell and colleagues used a building task with kindergarten children (mean age 6 years) and second grade children (mean age 7;11) (Flavell, Speer, Green, & August, 1981). Children heard ambiguous directions to make a building with blocks and were asked to say whether it looked exactly like the target, and whether the directions had done a good or bad job. Although the younger children showed some signs of problem detection (as in the non-verbal behaviour studies described above), they were less likely to do this than the older group and were worse at evaluating their success and whether the directions had done a good job. A second study confirmed that the younger children's difficulty was not caused by difficulties recalling the directions.

Two possible explanations of the younger child's behaviour are suggested by Flavell and colleagues: that young children's experience of comprehension difficulties when they hear ambiguous messages are fleeting and they might dismiss them as unimportant, or that they may be conscious of these difficulties but not realise their implications. I will explore whether children can produce apparently appropriate responses to ambiguous stimuli based on uncertainty rather than understanding about what it means for an input to be ambiguous. I hope to further our understanding of the relationship between problem detection, awareness of uncertainty about the target and understanding about what can be done to remove these feelings and resolve ambiguity.

Beal and Flavell (1982) investigated whether children might fail to evaluate ambiguous messages appropriately, because their feelings of uncertainty are fleeting. They also sought to emphasise the goal of the task, in case children failed to focus on this. The task

used a building task which was similar to that in the Flavell et al (1981) study (above), but there were three experimental conditions: an alternative building condition in which the child was instructed to build a second building which would also follow the instructions (the child was encouraged to do this, and if s/he did not, eventually the experimenter built a possible building for them); a task goal condition in which a building, “the one Sheri had made”, was placed under a cover on the table; and a combined condition where both these aids were used. There was also a control condition which had neither of these aids. Children in all four groups showed signs of problem detection (for example, a delay in responding, “puzzled facial expressions” and “wiggly body movements”) during building. In the evaluation task, however, children in the alternative building and combined conditions were more likely to answer that their building might be different to Sheri’s. As children’s performance was not improved in the condition where the target building was physically present (but hidden), the authors conclude that children’s poor evaluation of ambiguous messages is not due to feelings of uncertainty being fleeting but instead “a more fundamental metacognitive deficit in their knowledge about the communication process” (p48). Importantly, in the successful groups the experimenter pointed at the child’s first building when asking the questions. Children needed few prompts to build an alternative building and it seems likely that the child might have switched their allegiance to the new building. They persisted in claiming that Sheri’s instructions were good, and so rather than the alternative building alerting them to the ambiguity in the instructions, it might have indicated to them that the first building was wrong. This type of explanation is similarly helpful in my thinking about my first two experiments (see Chapter 2).

Intriguing difficulties with message evaluation were found by Robinson and Apperly (2001). They had previously investigated partial knowledge within the context of referential

opacity (Apperly & Robinson, 1998). Children have difficulty evaluating the knowledge of a puppet who knows one description of an object (that it is a dice) but not another (that it is a rubber), performing well on the question “Does Heinz know the dice is a rubber?” but not “Does Heinz know there’s a rubber in the box?” Similarly, on a message evaluation task, where possible referents were a red long balloon and a red round balloon and the child was told the balloon was red, they answered “no” correctly to a question “Did Heinz say that the red balloon was round?” but performed poorly when asked “Did Heinz say it was the round balloon he chose?” Clearly, evaluation of messages is not straightforward and children have problems distinguishing what was said from what was meant. Despite children’s problems with message and knowledge evaluation, children might show good performance on simplified non-verbal tasks, in which they are not required to consider the metacognitive aspects of the task. The apparent contradiction between children’s responses to Robinson and Apperly’s two ‘ambiguity’ questions, suggests that there is something especially difficult for the child in translating what was actually said into its consequences for communication and action. In this thesis I move away from these tasks, and investigate whether children might successfully employ more functional behavioural responses to ambiguous input.

### **1.5 Is the problem a linguistic one?**

A limitation of my argument that children have difficulty understanding ambiguous information is that the research I have presented thus far, is based on children’s understanding of ambiguous words and messages. However, there is evidence, presented in this section and in Section 2, that this problem extends to non-linguistic ambiguity. In keeping with Robinson and Mitchell’s finding that children can report ignorance under some circumstances, this supports my move to addressing the ability to handle ambiguity as a broad cognitive problem, rather than one specific to the communication process.

Robinson and Robinson (1982) compared verbal ambiguous input with visual ambiguous input and found there was no difference in 5- and 6- year olds' evaluation of ambiguous input. This persisted even when, in a second study, children themselves revealed ambiguous parts of the picture, to remove the possibility that children thought the partial view of a picture was a message.

It should be noted that Keil (1980) makes a contradictory claim to this, suggesting that there is something distinctive about linguistic ambiguity. The youngest children in his study were 6- and 7- year olds and I accept Keil's claim that children might have difficulties with some types of linguistic ambiguity even after they can handle the basic concept of ambiguity. However, we do not know whether these children would have passed the message or knowledge evaluation tasks described earlier. In his study, structurally and symbolically ambiguous pictures and sentences were compared. Keil defines a structurally ambiguous input as one which can be "broken up or parsed into two different meaningful structures" (p220), whereas a symbolically ambiguous input has two different possible referents (or interpretations), but these interpretations do not need to be broken up differently to appreciate this. For example a structurally ambiguous sentences was "Biting dogs can be dangerous", while a symbolically ambiguous sentence was "The lady had some nice glasses" (in the latter only the word "glasses" needs be interpreted differently to provide the two meanings). Structurally ambiguous pictures could be viewed as two different items, e.g. a horse or a seal depending, in this case whether one part of the picture was taken to be the horses ears or the seal's tail. These pictures are similar to the classic duck/rabbit picture, or the picture of a young or old woman, common examples of pictorial ambiguity. Symbolically ambiguous pictures included a drawing of two vertical lines and many short horizontal lines crossing them, which could equally well be a ladder or a railway track. However, it is difficult to see

why these verbal and pictorial stimuli are comparable in terms of difficulty, other than fitting Keil's description of structurally and symbolically ambiguous items. Furthermore, the testing sessions in this study were extremely long, taking up to an hour and a half and for some of the younger children this session had to be broken up to allow them to complete the tasks. Keil claims that linguistic ambiguity is distinctive, because of a correlation between the structural and symbolic linguistic stimuli. There was no correlation between pictorial and linguistic performance. Overall, the claim that even after one has the competence to handle ambiguous input, some types of ambiguity will be difficult to deal with is not one I would disagree with, nor is it inconsistent with my proposal that younger children might have problems handling ambiguous input, irrespective of its type. Often when a child has mastered a certain type of reasoning in one domain, s/he cannot apply it to another. (See for example, Piaget's notion of horizontal *décalage*: Children master conservation of mass at around the age of 7, but it is not until some years later that they are able to apply this concept to volume and then even later density. (discussed by Sutherland, 1992)).

In contrast to Keil's claims, evidence from Pillow and Henrichon (1996) and Taylor (1988), discussed in Section 2 of this chapter, support Robinson and Robinson's finding that children do have difficulty with non-verbal ambiguity and so in my study of young children's understanding, I will treat their difficulties with ambiguity as not confined to verbal communication.



## 2 Other approaches to difficulties with ambiguity: Interpretative Theory of Mind and Logical Reasoning and Undecidability

Several authors have been concerned with understanding of ambiguity in relation to other skills. In this introduction I will consider these briefly as supporting evidence that young children have difficulty with ambiguous input.

### **2.1 Interpretative Theory of Mind**

Understanding that other people have beliefs and desires that can differ from one's own, and that one's own beliefs might become outdated is an area which has dominated cognitive developmental research over the last couple of decades. It is widely acknowledged that children understand false beliefs by the age of 4, but the possibility of further development of their understanding about the mind remains controversial. The aspect of this which is of relevance here, is that of how children come to appreciate that a single input, might lead to multiple interpretations by different people.

Taylor (1988) based her work on the possibility that there are two stages to understanding about others' knowledge. In stage 1 children understand that without seeing an object, someone does not know about it. Stage 2 develops from this 'seeing equals knowing' rule to the understanding that the same information can lead to different interpretations, (Chandler & Boyes, 1982). In her task children were asked what a puppet would know about a picture, having seen only a small part of it. They were asked if the puppet knew its identity, what it was doing and a piece of personal information the child had been told about the picture (e.g. that it was a giraffe, sitting down, called George). Very young children, 3 year olds, tended to respond randomly or use a response bias (either to "yes" or "no"). About a third of the children aged 4- to 6- years tended to answer that the puppet would know about

the picture, if they had seen an ambiguous part of the picture. This type of responding accounted for only 1 of the 18 children in the 8 year old group. The 4- to 6- year old children were more likely to over-attribute knowledge of action information about the picture, than personal information. This suggests that their incorrect answers were based on a misunderstanding about the information available from a partial view of the picture. With training, which illustrated to the children the possibility of multiple pictures with the same restricted view, children improved on knowledge evaluation questions, and also 4 year olds began to ascribe blame to the game being too hard, rather than the puppet's guessing ability. This ability, to understand that there is something too difficult about the task, is interesting, because it moves us on from referential communication tasks, in which one attributes blame to speaker or listener. The children here might be able to acknowledge that there is a problem, and indeed that it is to do with the game, but have yet to realise what this problem is.

Similar problems with interpretation were found by Chandler and Helm (1984), who showed children pictures and asked them to judge what another person would know about it, having seen only an ambiguous partial view. There were differences in performance between 4, 7 and 11 year olds. Interestingly, the 7 year olds' performance was improved when they were asked to make an interpretation based on a partial view, before seeing the whole picture. Chandler and Helm interpret the youngest children's poor performance, where they tended to confound the other's knowledge with their own, as evidence for their egocentrism. Alternatively, we could describe their difficulty as a failure to realise that one input can lead to multiple interpretations per se. (The fact that you confound your own interpretation with that of another, does not tell us whether you would still have problems if there were two

others, see Pillow & Henrichon, 1996, below.) At the very least, this finding offers support to my claim that young children have difficulty with multiple interpretations.

In work by Pillow and colleagues similar difficulties with understanding multiple interpretations have been found. Pillow and Henrichon (1996) found that 4- and 5- year olds had difficulty understanding that two puppets, who had each seen the same partial view, but different complete pictures, would be biased in their interpretation of a partial view of a third picture. Furthermore, although children often attributed the same guess to the both the puppets, this did not always correspond to their own view, so the problem does not seem to be solely one of the child's egocentrism. In a later study children were found to have trouble explaining the source of such interpretation errors as well (Mash & Pillow, 1997).

Ruffman, Olson and Astington (1991) found contrasting results in their task in which children judged their own knowledge and that of a puppet who saw an ambiguous part of an animal (just its colour) through a window in a box. They attribute the success of children as young as 4 on their task to the increased salience of the perceptual cues children had to their own or the puppet's ignorance: great efforts were made to highlight to the child that the two possible referents were the same colour. The authors analysed ambiguity problems as being dependent on the same abilities as false belief. Children need to know that an ambiguous stimulus can be interpreted in more than one way, that because of this, a person might have a false belief about the item and consequentially that they will not know what it is. While this is a good analysis of understanding differing interpretations based on the same ambiguous information, the first requirement is my concern – understanding that a stimulus might have more than one interpretation. It is possible, in principle, that you can solve a false belief task without appreciating this aspect of the problem. Someone can 'simply' be wrong about a referent and the relationship between their interpretation or belief and the item itself is

unimportant. This anomalous result is useful to me in that it encourages us to move from such verbal knowledge (and message) evaluation tasks, to the behavioural tasks presented in this thesis. In particular I focus on the child's understanding that when the message itself is given, the intended target is unknown and so any of the potential referents are equally likely to be correct. My tasks offer children various behavioural strategies to deal with this uncertainty.

## **2.2 Logical Reasoning and Undecidability**

In the tasks I have considered thus far, children either hear an ambiguous message or see an ambiguous stimulus which is open to different interpretations. A second type of problem, which requires you to hold multiple possibilities in mind, is when a logical problem is presented that can have more than one solution. These studies offer a different framework in which to consider ambiguity.

Acredolo and Horobin (1987) explored children's capacity to identify multiple solutions to "indeterminate" problems. They used a task which required inferences to be made about the relative sizes of different balls. For each trial 12 balls were shown at the top of a computer screen, increasing in size from left to right. Responses were made by highlighting the section of balls which could fit the description. The child learnt two facts about the three target balls that were labelled A, B and C. For example, in a "determinate" problem the child might learn that "A is smaller than B" and that "either A or C is the biggest". The problem was illustrated by shading two of the balls on the row of 12 balls, these were A and B. The child's task was to identify which of the remaining possible balls in the row could be C. In this problem C must be the biggest ball and so the correct response was to highlight all of the possible balls to the right of the larger ball already shaded (which must be B). Notice that in this experiment there were two levels of ambiguity. All problems

required that the child shade more than one ball to respond correctly. So in this “determinate” example, if there were three balls to the right of B the child had to shade all of these as possible sizes for C. “Indeterminate” problems had multiple possible solutions in that the child had to highlight balls from more than one section of the row (the second level of ambiguity). For example, if you know that “A is smaller than B” and that “A is not the biggest” then C could be any of the balls remaining on the row. That is, it could be the biggest or the smallest ball or could be between A and B. To pass this trial, the child had to shade all three sections on the computer display (those to the left of A, to the right of B and those in the middle of A and B). Until the age of 12 (groups had average ages 6;8, 8;5, 10;7 and 12;2) children had difficulty accurately identifying multiple solutions, that is when balls had to be selected from more than one section. i.e. in the “indeterminate” and “partially indeterminate” problems (“partially indeterminate” problems allowed children to rule out one section of balls, but C could fall in either of the remaining two sections. I have made a similar distinction in my experiments between ambiguous input which allows you to narrow the range of potential referents (narrowing) and that which does not rule out any potential referents (uninformative)). Acredolo and Horobin refer to this tendency shown by the younger children as “premature closure” meaning that once children have found one possible answer to a problem they fail to search for more.

The use of the term “indeterminate” here is questionable. Indeterminacy normally describes problems which do not have a solution. Although there might be multiple possible solutions, what is important is that there is no one solution. All the extra information in the world cannot tell you, in this current state, what the answer to the problem is. This is different from an undecidable problem, say an ambiguous message that has an intended referent but, because of the multiple possible interpretations, one does not know it. In this latter case there

is one solution, it is just that we do not currently know it. Braine and Romain (1983) recognise that commonly there is ambiguity within ambiguity and logical undecidability tasks themselves, as to whether “can’t tell” means “I do not know” (what I am referring to as ambiguity) and “One cannot know” (indeterminacy). Piérait-Le Bonniec (whose study I report next) has found results which suggest that it is not until the age of about 10 that children come to appreciate this distinction (Piérait-Le Bonniec, 1980). For my purposes of exploring ambiguity, it is enough to note the difference between logically indeterminate problems and those which are undecidable. However, I claim that the three studies discussed in this section, which describe children’s understanding of “indeterminacy” are better thought of as examining undecidability. In Acredolo and Horobin’s study the child’s task is described as identifying the balls that “could be the *one* ball still hidden in the bottom box” (p15). Although all one can do in this task to answer correctly is highlight the possible answers, this does not change the fact that there actually is one answer: one is trying to identify which balls might be C, given that one ball is C. In the task used by Piérait-Le Bonniec (1980; and adapted by Fay & Klahr, 1996) the child is trying to work out which box of model pieces a model has been made from. Although more than one box might be possible, the piece must have been made from pieces in one box for this question to be posed. In fact, in the procedure the experimenter pretended that s/he was making a model from the pieces in one of the boxes (even though in fact the model was not made from pieces in either box, but was readymade, this does not make the problem in the task indeterminate). If we were to change the problem and had two boxes with oranges in them and posed the question where does a single new orange go, it would be reasonable to argue that this is an indeterminate problem. There is no one right box: the orange could equally well go in either box. However, the finding that “undecidable” is difficult for children to acknowledge using a “can’t tell” response, remains

relevant (perhaps more so) to our question of whether children have difficulty with ambiguity.

As I have mentioned, in Piéraud-Le Bonniec's study (1980) children saw objects which could be made from the components in two boxes. The child's task was to identify which box the object in question could have come from. Five year olds showed a strong tendency to identify one box as the correct box, even when the object could have been made from either box. Children who agreed, having made their decision, that the other box could have been correct, still claimed to know which box was correct. As I discussed in relation to Beal and Flavell's (1982) finding (this chapter, Section 1.4), it is possible that children were prepared to switch their choice to the other box, on suggestion that their first choice was wrong, without appreciating the ambiguity of the original problem.

In a development of this procedure (Fay & Klahr, 1996) children were asked both to justify their choice of box and probed as to whether the other box could have been the right one. Then they were asked a final 'can/cannot tell' question about the trial. Performance was better than in Piéraud-Le Bonniec's study, but many children continued to claim the problems were decidable, even though children were good at identifying the possible multiple referents. Fay and Klahr suggest that dealing with this type of problem requires three stages – search, evaluation and mapping. From their manipulations of the procedure they suggest that although with help children can identify multiple possibilities they found difficulty with the evaluation stage – realising that the existence of multiple possibilities should lead to a judgement that the problem is undecidable. Children's identification of multiple referents was based on answers to a probe "Could I have used the other box to make this?" asked after the child had said that one could tell which box the model had come from. Once again (as in Beal and Flavell, 1982 and Piéraud-Le Bonniec, 1980), this does not tell us that the child realises

both boxes were equally plausible answers to an original question, as they may have switched to an alternative certain answer. In Fay and Klahr's study children did perform better on a final test question about whether this was a trial where one could or could not tell than on the initial asking of this question. The probe may have alerted them to the possibility of multiple potential referents. However, performance was better on the probe question than on the second "can/cannot tell" question. So my suggestion that children do not realise that there are two simultaneously possible referents is still a possibility.

### 3 Strategies

The tasks described above tended to rely on the child being able to convey verbally the limitations of the ambiguous input. It might be that although explicit evaluation of ambiguous input is difficult, the child might have an 'implicit understanding' s/he can employ to deal with such input effectively. Such a distinction has been suggested in related areas of developmental research, such as Theory of Mind (see e.g. Clements and Perner, 1994). In this area of research explicit understanding is evidenced by children's correct responses to a verbal question about a character's false belief "Where will Maxi look for the chocolate?" Some children who failed this explicit test systematically looked towards the correct location, which has led to a proposed earlier developing 'implicit understanding' of false belief (Clements and Perner, 1994; Garnham and Ruffman, 2001).

Use of the terms implicit and explicit has resulted in much controversy within both the developmental and broader psychology literature. All too often the terms are undefined, or assumed to have vague folk psychological meanings: broadly that explicit describes conscious verbalisable understanding, and implicit describes skills or knowledge which people are unaware or unconscious of using. Under this use, implicit knowledge is often characterised as the same as explicit knowledge but inaccessible to consciousness. The term



can become a bucket term, used to describe any abilities which appear inaccessible to consciousness, without a more careful analysis of the knowledge or skills the child has.

Useful work accompanying the increased use of the implicit/explicit distinction in developmental psychology has been done by Dienes and Perner (1999). They use the term implicit to describe knowledge or information which is implicit in other knowledge. This is in contrast to characterising it on the basis of its inaccessibility. In an example they use, if someone uses the word “bachelor” it is implicit in this that the person being described is “male” and “unmarried”.

Using the example from Theory of Mind, it might be that children have an inaccessible but genuine understanding of false belief (the first use of ‘implicit’). Alternatively it might be that some other knowledge prompts their eye movements, and although it is ‘implicit’ in their behaviour that they understand the consequences of false belief, it would be wrong to think that the child actually possesses any actual knowledge that we could call implicit. This distinction between ‘inaccessible implicit knowledge’ and ‘knowledge implicit in X’ will be important in my discussion of what constitutes and understanding of ambiguity in Section 5 of this chapter.

Without necessarily drawing such a clear distinction between implicit and explicit abilities, it might be that children can act on their knowledge about something without being able to respond in the way the task demands: that is they may be able to handle the information behaviourally without making formal evaluations of it (for a dissociation in a related area of research, see Whitcombe & Robinson, 2000).

Hence, one line of research within the field has been to explore whether children might in fact reveal a competence regarding ambiguity, if they use skills other than the verbal evaluation skills demanded in the linguistic tasks above. I will describe two lines of work

which seek to reveal children's abilities to use alternative strategies. Firstly, an exploration of whether having to say "can't tell" is particularly problematic for young children and secondly, whether alternative strategies such as making tentative guesses or asking questions are more suited to the child's skills.

### **3.1 Attempts to use a "can't tell" response**

Braine and Romain (1983) reviewed the literature on children's ability to judge problems as "undecidable". They suggest that there is a response bias against saying "can't tell" for various reasons: that people expect more problems involving syllogisms to be decidable than actually are; because there is a loss of face in admitting 'failure' by admitting you don't know; they may misinterpret the premise (in their example "If there's a cat in the box there's also an apple. There's a cat. Is there an orange?" answering "no" might be the result of reading the first premise as meaning "only an apple"); they may be too hasty to decide rather than explore alternative possibilities; and finally people are probably biased towards making decisions rather than shelving them – hence a 'poorly based decision' is preferable to no decision. It is possible that children's difficulty with ambiguity tasks, is that they find it difficult to use a "can't tell" response. Here I will briefly consider attempts to facilitate children's ability to respond "can't tell" which avoid making a verbal evaluation of this, i.e. saying "I can't tell". It is worth remembering here Braine and Romain's observation of the confound between the meanings "I can't tell" and "It cannot be known".

Several studies have attempted to change the response from saying "can't tell" to some behavioural analogue of this. Somerville et al (1979) used a task in which children had to identify a correct location, given a clue. When the locations were similar on the relevant feature, i.e. the clue they heard was ambiguous, children had difficulty making a "can't tell" response. This persisted when the type of response was changed to "ask the man" – a

response which meant the child didn't have to admit failure, and could be seen as continuing towards the original goal.

Ackerman (1981) suggested that children's difficulties may be the result of a "performative bias", which he clarifies in a later paper (Ackerman, 1986) as meaning that children have a bias to choose a referent. Children in his study were asked to attribute messages to one of two speakers and so their response was not to evaluate their knowledge or ignorance, but to choose the most likely speaker. Young children, 5- to 6- year olds, were better at ascribing message to the appropriate speaker when the choice was between a selfish or nice character, than when they chose between a stupid or smart character. Ackerman then offered children a "can't tell" response in the form of a picture with a large X through it, and found that children were most likely to use this response appropriately if they were reminded before each trial of the need to "know exactly which one is right". Performance on two separate conditions, although both worse than this reminder condition, was better when children were told the messages had come from a character who sometimes might be selfish compared to a character who might not give good messages. This work highlights the possibility that children do make interpretations of ambiguous messages because they think this is most appropriate, Ackerman's performative bias, but I believe that the difference between performance on "selfish" and "stupid" trials, suggests that children might also be able to identify messages as poor, without understanding why this is. Ackerman claims that superior performance on the "selfish" trials, is caused by children attending to the locutionary content of the message, rather than the performative use of communication. However, it might be that because the speaker is characterised as potentially selfish, children find it easier to rate some of his messages as bad when they lead to feelings of uncertainty, whereas in the performative conditions, children are directed to think about the message itself – is it good or

bad – which involves more understanding of why a message might be problematic. The children's success in using the crossed out "can't tell" response, suggests that their difficulty is not specifically in using this kind of response, but further work is needed to pinpoint what children do and do not understand about the limitations of ambiguous input.

This work was followed up by Robinson and Whittaker (1985) who noted that Ackerman's performative bias could mean a tendency to choose a referent or more broadly a tendency to interpret utterances as "requests for action". They used a task in which children heard a message which could refer to one of several dolls. In a standard condition the child had to choose a doll if they knew the referent, or point to a "mystery man" if the message was ambiguous. So, the mystery man is a non-verbal way of saying "can't tell". In a second condition the child had to instruct a puppet to pick a referent or choose the mystery man. Discrimination between ambiguous and unambiguous messages was better in this second condition. In a second experiment, there was no difference in performance when children were asked to point at the mystery man when they did not know, or when they were simply directed to tell the experimenter. Robinson and Whittaker interpret this as showing that children are biased to making an interpretation (which is not immediately available in the condition where children instruct the puppet) rather than simply making a physical response. For this section of my introduction, the studies show that the difficulty children have with ambiguity tasks is not easily removed by changing the type of "can't tell" response from a verbal one to a behavioural one.

Fabricius, Sophian and Wellman (1987) offer supporting evidence to the claim that young children do not have difficulty with a "can't tell" response *per se*. Their study was concerned with children's understanding of logical necessity. The child's task was to open one or both doors on model houses to find the target. Fabricius et al sought to remove

referential ambiguity from their task. There was no speaker giving an ambiguous message to identify a referent, instead their interest was in the inferences drawn by the children once the first door had been opened. Sometimes the information behind the first door was sufficient to indicate whether this was or was not the target (e.g. person present when the clue was “a person in the house” confirms, when the clue is “nobody in the house” disconfirms). On other trials, the information revealed by the first door was insufficient and the second door needed to be opened (e.g. if the rule was “both doors have people” and the first door reveals a person). This procedure neatly integrates a seeking information response into the strategy being used in the game. Children showed a complex pattern of responses, indicating a developing understanding of logical necessity. Both 3 and 5 year olds discriminated confirmatory trials from insufficient ones. Although 5 year olds discriminated insufficient trials from disconfirmatory ones, they still searched the second door on 60% of disconfirmatory situations (i.e. where the rule is both doors will have people, and the first door has nobody behind it). The 3 year olds’ performance was more complicated. They had particular problem with insufficient trials where the rule was “an X” and the first door showed no X failing to discriminate these from disconfirmatory trials. They also searched the second door on 63% of the disconfirmatory situations. Most importantly, a second task included a judgement task where some doors on houses were open. The child had to evaluate his/her knowledge, rather than be proactive in seeking new information. In contrast to the suggestion of Braine and Romain (1983), Fabricius et al did not find a bias against saying “can’t tell” as there were no more inferences drawn in the judgement condition than the search condition.

The evidence is against the possibility that specifically saying “can’t tell” is a central problem for young children. Children have difficulty evaluating themselves as not knowing,

whether the response they are asked to make is verbal or behavioural, even when it is very well matched to the knowing response (as in Robinson and Whittaker, 1985). However, in Robinson and Whittaker's study the alternative response was final, an explicit marker of lack of knowledge, and the child ended the trial without having interpreted the message.

Somerville et al and Fabricius et al used a "can't tell" response, seeking new information, which would still progress children towards their goal of interpreting the message, or resolving the ambiguity. Yet the response in Somerville's study is a verbal one, the child had to say that s/he wanted to "ask the man".

To make claims that young children do not understand ambiguity, we need to move to tasks which do not demand reflective or evaluative admissions of ignorance. To give children the best chance of revealing competence on an ambiguity task, I will draw on Fabricius' approach, in which seeking new information aids one in making an interpretation. I will also use non-verbal tasks, as despite the findings reported above that children's difficulties with a "can't tell" response are not limited to verbal measures, I want to remove the reflective elements of earlier research, in the hope of revealing children's competence.

### **3.2 Alternative strategies**

Although the child's difficulty seems not to be the result of a bias against saying "can't tell" children's abilities may be underestimated by the verbal evaluation tasks used. In this section, I consider various attempts to encourage children to use alternative strategies.

#### *Guessing and making strategic interpretations*

When someone encounters an ambiguous input, one strategy is to make a tentative interpretation of it, or a guess, despite knowing that the input in fact has multiple possible referents. In some circumstances, it might even be appropriate (socially, if not logically) to

claim that one knows that one has ‘guessed’ the right item. In many games the purpose of playing is defeated if one refuses to guess unless absolutely certain.

Speer (1984) proposed that young children might not have trouble understanding the informational limitations of ambiguous messages, but might instead be using strategies to respond that would not be expected or thought entirely logical by adults. He suggests that children’s behaviour could be explained if they were trying to use contextual clues to identify a referent and if this failed made a guess, expecting corrective feedback. Speer found evidence that children employed clues available to them – when given a choice of red and white potential referents or near and far potential referents, they tended to choose the red or near one, following what Speer describes as a saliency strategy. Children were more likely to say that they “knew for sure” that they had chosen the correct referent and were more confident when saliency clues were present. He tested his proposed guessing strategy by manipulating when the child gave an estimate of confidence in their interpretation. Children made estimates either immediately after making the interpretation, or after the experimenter had turned away (in a first experiment) or got up from the table (second experiment). Evidence for the guessing strategy is less clear than that for the saliency strategy. This guessing strategy predicts that if the opportunity to be corrected has passed, then the child should be more confident in his or her interpretation. In Speer’s first experiment where the experimenter remained seated at the table and looked away, there was no difference in confidence, but in the second experiment, where the experimenter left the table, children were more confident under this condition.

Although Speer uses these findings to claim that children are indeed using a combination of his two strategies, I want to argue that this explanation cannot tell us what children understand about the limitations of the ambiguous input they heard. I acknowledge

that they do tell us about how children deal with information in the world – especially information which they might find confusing or difficult (and there is evidence from the non-verbal literature that children detect some kind of problem with ambiguous input). However, Speer's pattern of results would be seen if children did not realise that the message was problematic because it referred to more than one referent and that to make an accurate interpretation they would need to find out more. In other words, if they did not know that it is ambiguous. In this case children are looking for the (one and only) correct referent of the message and to do this they might sensibly take a contextual clue (the colour or position) to mean this is the correct referent.

As to Speer's guessing strategy, I question whether this tells us that the child knows that their interpretation is as likely to be right as the alternative. That the child's confidence increases when the experimenter has moved away from the table before the question is asked might suggest that they have felt some uncertainty in their interpretation which is removed (or lessened) when the opportunity for feedback has gone. However, it does not necessarily show that they understand why this uncertainty arises nor that the original message is ambiguous, and so that they were actively making a guess. It might be that confidence in one's interpretation of an informative message increases as the potential for correction decreases.

Further evidence that children use strategies to respond to ambiguous messages comes from Jackson and Jacobs (1982) who found that 6- and 7- year olds tended to use a maxim of antecedence: they tended to choose the referent which had previously been identified. Also, Ackerman and colleagues, found that under some (but not all) circumstances, young children (5- and 6- year olds) were able to use common ground information to predict people's interpretations of ambiguous messages (Ackerman,



Syzmanski, & Silver, 1990). However, the young children in this study still had difficulty identifying when the person would not know the intended referent and also confused what was said with what was meant (see also Robinson, Goelman, & Olson, 1983). As with Speer's saliency strategy, if children systematically choose certain referents, this might mean that they are making a strategic guess. But, as I have argued, it might equally well mean they are making a confident interpretation, thinking that they can use the clues available to find the correct referent.

### *Seeking new information*

It is likely that in verbal communication the interactive nature of conversation is integral to disambiguating messages. In real world situations, people have the opportunity to respond to ambiguity by seeking new information. In a study that addressed this directly, Krauss and Weinheimer (1966) asked adult subjects to participate in a communication task, in which they had to describe unfamiliar shapes to an unseen listener. When listeners were allowed to give concurrent feedback, speakers' messages became more efficient over a series of trials, compared to subjects given no feedback aside from the accuracy of the listener's choice. There were no restrictions on what listeners could say and this study has been interpreted as showing that in normal conversation-like communication, listeners and speakers work together to reach an efficient communication strategy. Krauss and Glucksberg (1969) ran a similar task with young children, in which a speaker had to identify blocks marked with abstract shapes and communicate this to a listener (of the same age). Children were tested on eight trials and within each trial they had to identify 6 blocks. Like the adults in the experiment above, children over the age of 8 improved their performance quite quickly, greatly reducing the number of errors they made. However, the youngest children tested 5- and 6- year olds learnt little from the repeated trials and a sample of 6- and 7- year

olds reduced the number of errors, but did not attain the success of the older children. There were no restrictions made on what the children in the speaker and listener roles could say to each other, and the results suggest that the younger children did not improve the adequacy of their messages given feedback, either from a listener or when they saw the mismatch between their blocks and the listener's. However, this study used children of the same age as listeners and so it is likely that any requests from them for information, would have increased in sophistication with age. Furthermore, complex abstract shapes were used, which the younger children might have found especially difficult to deal with.

Despite this reasonably poor performance, it is still reasonable to ask whether children might perform much better on tasks where they can seek new information, rather than evaluate an input out of context. Although Krauss and Glucksberg's work can inform us about children's co-operative communication, other researchers went on to focus more closely on the individual child's ability to deal with ambiguity by asking questions when s/he does not know the intended referent. Ironsmith and Whitehurst (1978a, 1978b) conducted two studies in this area. In a first study (1978a) children heard ambiguous and unambiguous messages about an array of pictures and had a choice of two responses. If they knew which picture the message referred to they were to push the button which corresponded to the picture, if they did not, they were to ask a question. (Note that in this and all the question asking studies in this section, the responses were asymmetric: interpret if you know, ask a question if you do not.) Responding appropriately to ambiguous messages (by asking a question) increased with age. The youngest group of children (mean age 5;6) averaged just over 1 correct response to ambiguous messages of a maximum score of 10. Furthermore, when the type of questions asked were categorised the older children (mean 9;7 and 11;8) asked more specific questions than the younger groups (the second youngest age group were

aged 7;9). Clearly the youngest children, in the age range I am interested in for my thesis, had real difficulty using this alternative strategy.

In a second study (1978b) the authors attempted to model question asking to see if this would improve the younger children's performance. Modelling specific questions or a question asking strategy (asking a specific question and explaining why it was necessary) increased the number of appropriate responses from 5- and 6- year olds (both these modelling strategies and modelling general questions improved performance in an older group of 7- and 8- year olds), but modelling had a greater effect on the older children. After the modelling intervention there was still a significant effect of age. Ironsmith and Whitehurst are cautious about the apparent result that modelling improved the performance of the younger children, given the much greater effect it had on the older children. They also highlight a possible strategy being used by the younger children which was to mimic the strategy model's entire utterance "It must be one of these two. They're both round and big. So which one?" Although they present no direct analysis of this type of response, it is useful to note here children's ability to adopt a response strategy while, possibly, not understanding its real relevance. This is something I will return to in my experiments (see Experiment 3, 5 and 6). Overall, Ironsmith and Whitehurst's results, show reasonably promising (but not perfect) abilities in older children and some effects of modelling for children older than 7. However, the younger children's difficulties responding to ambiguity persist.

Similar results are reported by Cosgrove and Patterson . In their study children had to identify pictures from an array. Half the children were given a plan which was to ask questions if they did not know the intended referent. This plan had an effect on older age groups (including 6 year olds) but not on their youngest age group of 4 year olds. They also included two types of ambiguous messages – those which I will refer to as narrowing (an

ambiguous message which rules out some of the possibilities) and those which were uninformative and could equally well refer to any of the potential referents (in Chapter 5 these are described as useless). Questions were rarely asked in response to narrowing clues. This is important for the interpretation of what the plan does. Children might learn from the plan that they have a good strategy to use when they have a very bad message. However, if they do not realise the strategy's applicability to situations when they can reject some pictures, those with narrowing messages, then children are not effectively using this problem solving strategy to deal with ambiguous input. Thus, these results do not show children revealing an understanding of ambiguity through their question asking.

Finally, in a more recent study, Lloyd, Camaioni and Ercolani compared question asking by 6 and 9 year olds in a cross cultural study of English and Italian children (Lloyd, Camaioni, & Ercolani, 1995). Once again, children played a communication game, in which they had to identify cards given ambiguous and informative messages. They were encouraged to ask questions "If you are not sure you can ask me questions until you are sure you have the right one" and if children hesitated they were prompted. If they answered that they didn't know which one it was the experimenter prompted with "Why? What do you need to know?" Despite this, on nearly half of the ambiguous messages 6 year olds chose a referent immediately. With regard to the cross cultural comparison, the Italian children were less likely to choose a referent immediately and benefited more from the feedback they were given (children were shown a mismatch between their choice and the intended referent when they chose before all relevant information was identified). In fact there was no main effect of age for the Italian children. Performance by the English 6 year olds was very poor – less than 10% consistently appraised message effectively (although this only rose to 20% for the 9 year olds) and once again, the results suggest that the English children younger than 7 did not

reveal 'hidden' understanding of ambiguity when they were able to ask questions, rather than make an evaluative response. One difficulty with this study is the difference between the two nationalities. Although in general children have difficulty asking questions to disambiguate messages, the success of the younger Italian children should make us cautious of these results. Differences in understanding the appropriateness of questions are another reason to use tasks in which children can seek information in a very simple non-verbal way, before claims that children do not understand how to disambiguate messages. This reasoning led me to develop the seeking procedure I have used in this thesis.

#### 4 A functional application of executive function

Before introducing the main body of the thesis, a second area of literature needs introduction. Executive function (EF) is a widely used term describing the planning, organisational and control processes which coordinate cognitive abilities. For example, Pennington and Ozonoff (1996) suggest "set-shifting and set maintenance, interference control, inhibition, integration across space and time, planning, and working memory" as a typical list of executive functions (p55). Definition of the specific processes included is notoriously problematic and most research relies on a functional approach, identifying from the top down the uses to which the alleged executive functions are put, such as the description given above. Despite these difficulties in defining precisely what we are concerned with, the concept has been used extensively in psychology, in the adult and clinical literature and increasingly in developmental research.

My purpose for introducing this literature is to explain the approach I have taken in the experiments which follow. My approach has been to address the information processing skills which might be difficult for children confronted by the most simple ambiguity tasks. Under this analysis dealing with ambiguity is a process which requires holding in mind

multiple alternative possibilities, resisting (or inhibiting) making an interpretation when insufficient information is available and planning which of a set of strategies might be most appropriate. To draw parallels between this analysis of ambiguity tasks and executive function tasks is irresistible.

In this section I will review aspects of the executive function literature which will be of relevance to this thesis, but this will remain broad and inevitably will not cover the intricacies of the research area.

Attempts to define executive functions have often begun with identification of the prefrontal cortex, an area comprising about half of the frontal cortex in humans (but smaller in non-human species), as having particular responsibility for these processes (e.g. Hughes, 1998; Russell, 1999). Evidence for these regions' roles in EF comes from patients with lesions to these areas who frequently show disorders of these skills. Although traditionally the frontal lobes were thought to be fully functional in only adulthood, there is good reason from both developmental psychology and neuroanatomy to think that there might be fledgling executive abilities even in preschoolers (see e.g. Espy, 1997).

Importantly, although the prefrontal cortex is a starting point for research into EF, it is acknowledged that the mapping between the brain area and the functions themselves may not be perfect (Welsh, Pennington, & Groisser, 1991). For the purposes of my research, it seems most profitable to recognise the likelihood of a major role for the prefrontal cortex in EF, but to think about the EF as processes, which are conceptually rather than necessarily biological linked.

Adult cognitive and neuropsychological research have highlighted several areas of interest concerned with executive function. I report here those which are the most relevant background to thinking about the development of such skills. Firstly, there is interest in

implicit and explicit executive skills. A dissociation between performance and explicit report is described in the literature. For example, Milner described patients who could report a correct strategy on tasks, but failed to use it, and even evaluated their performance correctly as “wrong” but perseverated with it (Milner, 1963). In such cases, there is an apparent split between the individual’s explicit knowledge about what should be done and his/her ability to perform the behaviour need to attain this goal. For my work this raises a question of ‘where’ the child’s difficulty might lie in dealing with ambiguity. It might be that they have difficulty in processing the information, that they do not understand that the ambiguous input can have more than one input and hence are helpless to work out how to respond to it. Alternatively, their problems might be similar to the patients described above, that they understand what is limited about the input they have, but are unable to put this into practice. Although unlike the adult patients they cannot articulate this dissociation.

Secondly, it is an area of debate as to whether EF is a single item or process, or dissociable into related but distinct control processes. It has been found that patients with dysexecutive syndrome show clusters of symptoms (described by Burgess and colleagues as inhibition, intentionality (planning and decision making), executive memory (confabulation and perseveration) and atypical positive and negative affect (Burgess, Veitch, Shallice & de Lacy Costello, 1998). Similarly in the developmental literature factors comprising EF have been suggested. One study using a battery of tests with preschoolers found three factors: working memory, inhibitory control and attentional flexibility (Welsh et al, 1991). For developmental research this approach is useful in exploring how children’s developing EF affects their performance in other domains. For example, Hughes (1998) finds general links between EF and Theory of Mind, but finds more specific links between deception tasks and inhibitory control. However, this approach has difficulties in that preconceptions about the

factors we expect to find seem to influence the battery of tests used to divide up the EF. It also leads us to think of the EF as a supervisory system, coordinating functional lower level processes. This is itself a contentious issue which will be discussed further when we come to consider Russell's work on performance and competence accounts of EF. This leads us into a third area of debate.

This debate within the adult literature is whether EF should be seen as the product of a central executive or processor. Famously, Baddeley and Hitch's (1974) working memory model involved a central executive, which acted as a controller and overseer of "lower" processes. This has been strongly criticised as a homunculus (e.g. Allport, 1993). One of the particular problems with the homunculus type central executive is that it relocates the control processes within the central executive, without necessarily giving us any clarification as to how they might function. Notably, Baddeley has acknowledged that this early description of the central executive "serve[d] as little more than a ragbag" (Baddeley, 1996) and even more recently has suggested that the central executive will almost certainly be found to comprise of subsystems (Baddeley, 1998).

Developmental psychologists have adopted varied approaches to EF. What is striking about the proposals from this research field is how the differences in the authors' conception of the problems of EF affects their investigation of the development of these processes. To set the scene for this thesis, I will briefly contrast three developmental theories of EF: Perner's, Zelazo's and Russell's.

Perner (1998) begins his analysis of the EF by relating these functions very closely to our conscious experience. He takes a top down approach, identifying the EF as linked in the way they allow us to "take a stance towards one's own volition". Perner bases his analysis of the EF on Norman and Shallice's Supervisory Attentional System (1980) (discussed more



recently in Shallice and Burgess, 1993). In doing this he does ascribe to the EF a coordinating role, but it is the role of conscious awareness where Perner sees the main special features of the EF. He describes them as our abilities to:

- feel in charge and responsible for actions
- be conscious of actions
- talk about and justify these actions
- follow verbal instructions
- and that we have limited capacity for carrying out actions simultaneously

Perner's interest in the EF is closely linked to how they might relate to Theory of Mind (ToM). He suggests (in contrast to authors such as Russell, 1996) that the EF might be dependent on ToM abilities. He argues that representation of one's own goals and intentions requires ToM skills. He explains links between ToM and EF by reasoning that if one has problems with ToM skills then EF (representation of goals and intentions) will be impaired.

The question of whether the EF are dependent on ToM skills (Perner) or give rise to them (e.g. Russell, 1996) is not central to my work on how EF skills might be related to understanding of ambiguity (if they are). But it is important to consider how identifying the EF as the providers of conscious experience might affect what we expect children to be developing. Perner's inclusion of verbalizability in the key features of EF seems to add extra demands to children's performance on EF tasks. It seems to me not unreasonable to think that some tasks might be completed which require coordination functions of EF but which the subject cannot verbally describe. For example, Ward (1998) used a task modelled on the complex real world example of making dinner, assuming that this required inhibition of certain responses, scheduling of subtasks, maintaining a goal etc, all thought to be EF. But although we would expect an adult to be using coordinating EF in performing such a goal, it

might not necessarily be that they could describe the process accurately. Furthermore, as described above, there are reports of patients who had problems with EF tasks, yet managed to verbalize their goals or acknowledge appropriate strategies, while continuing to make errors. For the approach I will take investigating whether the EF are involved in the development of dealing with ambiguity, I suggest that the criterion of being able to talk about and justify our actions is not a key part of how I shall view the EF.

A somewhat different approach to EF is taken by Zelazo and Frye in their work, in which they identify the EF as responsible for “deliberate problem solving”. Like Perner and unlike the clinical work identifying possible components of EF, Zelazo and Frye's definition is a ‘top down’ one, identifying what the EF are collectively involved in. Unlike Perner their definition is a functional one and is based more on information processing rather than the EF’s relationship to consciousness. They divide up problem solving into four stages: problem representation, planning, execution (intending) and evaluation.

Zelazo and Frye (1998) suggest that the problems children have with certain tasks can be understood using their ‘Cognitive complexity and control theory’. This proposes that children’s difficulties arise from an inability to coordinate increasingly complicated conditional rule systems. Their theory characterises the information processing that the child is engaging in as the development of a system of rules, and it is problems with the hierarchy of these rules, rather than following the individual instructions represented by the rules, which cause children to fail certain tasks. Much of the work to support this is based on experiments with the Wisconsin Card Sorting Task (WCST) and preschool children. Within this game, it is proposed that the child has to create setting conditions or higher order rules “which game it is” over and above what to do with an individual card. So the child has to represent “If it’s the shape game [setting condition]... then blue car here, red flower there”

and “If it’s the colour game [setting condition]... then blue car there, red flower here”.

Although the child would be able to play either game independently it is claimed that the coordination of these setting conditions above the game rules causes the child problems. The child fails to shift between the two sets of rules, and Zelazo et al describe this as an abulic dissociation, in which someone has knowledge but is unable to use it.

Zelazo and Frye differentiate between the coordinating role of EF and inhibition. They acknowledge that children (although generally younger than those with whom this thesis is concerned) are known to have problems inhibiting prepotent responses in some circumstances (see e.g. Gerstadt, Hong, & Diamond, 1994). They also identify children’s difficulties which could not be due to an overlearned response. Three year olds showed perseveration after only one trial (before the response could have been rehearsed enough to be thought prepotent) (Zelazo, Frye, & Rapus, 1996). Furthermore, when children watched a puppet play the game and were asked to evaluate his behaviour, their evaluations were consistent with the errors when they performed the task themselves. In other words, when the puppet perseverated they judged him as correct, when he switched between sets of rules they judged him as incorrect (Jacques, Zelazo, Kirkham, & Semcesen, 1999). This procedure should remove the demands of inhibiting a response, as the child has only to watch what happens and assess, with hindsight, how successful it was. If the child’s problem was with inhibiting a prepotent response to follow one established set of rules, but in fact they had the competence to switch between both sets ‘beneath’ this, then the 3 year olds should have performed well on the evaluation task. The authors conclude that the young children’s difficulty with the WCST is not one of inhibition: “3 year olds have difficulty formulating what should be done, not just difficulty doing it.” (p 124).

These findings have been further explored by Towse, Redbond, Houston-Price and Cook (2000), who report that children only make the post-switch errors, so central to the above argument, under certain circumstances, in particular when no demonstration accompanied the verbal explanation of the post switch rules. They interpret their findings as suggesting that the environment does place inhibitory demands on children and propose that the child need not even embed rules to pass the test – rather they could abandon one set of rules in favour of the new set.

Towse et al's results present a convincing reason to rethink the original analysis of the executive problems that may lead to failure on the card sort task. For the purposes of thinking about ambiguity and EF, I shall take on board the possibility that children could have problems on an EF task, such as (although possibly not) the WCST, when they are competent at the elements in isolation and their failure cannot be attributed to inhibition. This suggests that children can have a problem with coordinating their skills. The EF in this type of model are conceived as either a scheduler or a homunculus. The former, an organisational tool, which coordinates the other processes seems too automated to play the grand role assigned to the EF. In contrast the homunculus is avoided by many because it has so much conscious control, in using it we seem only to shift the problem of how these processes work on to another level, rather than solve it. It seems wrong to think that by describing the child's EF problem on these tasks as one of coordination we have solved the problem. Is it really useful or justifiable to characterise the young child as having adult like skills but inadequate abilities to integrate them? Also, if this were the case, that the child could perform these tasks if it were not for the coordination complexities, then we might expect many more insightful reports of the type we have from some dysexecutive patients.

It is at this point that Russell's work on EF might offer an alternative to the ways in which I have conceptualised EF so far. Russell (1996) introduces a distinction between executive performance and executive competence errors. The two types of executive errors, performance and competence, indicate very different underlying abilities in the person concerned. A performance error can occur when a person has the knowledge needed to succeed on the task, but gives an incorrect response. In this case competence might be masked by perseveration or using a prepotent response. The latter can be prompted by salient features of the environment or the way in which the person has conceived the task. For example, the typical error on the Wason Card task, where adults typically fail to turn over the card which would disconfirm the hypothesis, is described by Russell as a performance error (Russell, 1999). This is because when the mistake is pointed out to the adult, s/he tends to recognise what went wrong. Russell argues that adults have competence in understanding the logic, but on first sight of the problem are distracted by hypothesis supporting evidence to select the wrong cards.

On many tasks children seem not to be making what Russell would deem performance errors: for example, they fail to change their behaviour after correction as in Zelazo et al's work. Russell introduces the idea of executive competency to account for such findings. This is an ability to think "explicitly and at will" about the information you are trying to deal with. The EF in a competence account are not a final level coordinator or overseer. They are not allowing you to respond to a problem using underlying 'lower level' processes, but instead are integral to your being able to conceive of the problem. This account of EF has the attraction of avoiding criticisms that the EF act as a homunculus and also that we do not have to imagine that the child's 'lower level' skills are already developed and effective but masked by executive processes.

My intention in this thesis is not to redefine children's difficulty with ambiguity as one of executive function. Rather, I intend to use this EF research as a framework to guide my analysis of what skills might hinder children on these tasks. The most obvious application of the executive literature to ambiguity is the possibility that children's skills may be masked by a performance error. That is, that although they have the 'understanding' to handle ambiguity, they fail to inhibit their tendency to make an interpretation. If this is the case, I can make several predictions about children's behaviour on new ambiguity tasks:

- they should make interpretations of ambiguous input, but be flexible in their dealings with these interpretations
- performance should improve if the opportunity to make an immediate interpretation is removed
- reflection on or evaluation of another's responses to ambiguous input should be easier for young children, than those which require that they act (a similar logic to Jacques et al, 1999).

These possibilities will be tested in the experimental work in this thesis.

Although I do not want to pre-empt my experimental findings, I will introduce here the possibility that I might find little evidence for the child's difficulty being a performance error. If I hypothesised that the child has a competence problem concerning "ambiguity" as a whole, then one possible approach would be to compare ambiguity tasks with those of executive function and look for correlations. Indeed this may be a very useful approach if children's difficulties seem insurmountable. However, I argue that it is neither necessary nor helpful at this point to think of handling ambiguity as a single skill. Rather we might look to see whether there are aspects of handling ambiguity on which the child can succeed. To do this I will, in a sense, borrow from the researchers who have sought to break down EF into its

component processes (e.g. Welsh et al, 1991) and use these to analyse children's skills for handling ambiguity. In particular, I consider the high level skills which we might term planning and goal oriented behaviour. In the first two experimental chapters I offer children alternative strategies to handle ambiguity, to investigate whether they can work out what are the limitations of such information when the planning demands of selecting an appropriate strategy are changed. In later experiments, in Chapters 4 and 5, I change the goal of the game so that the child's task is no longer one of planning what is the appropriate final response to ambiguous input.

I acknowledge here that one central aspect of handling ambiguity is holding more than one potential referent in mind. This would be well translated in to a working memory demand. I do not address this demand directly in this thesis. Previous attempts to explore this (see Campbell, 1996) through attempts to get children to acknowledge the multiple referents of an ambiguous message have met with little success, and hence leave us no better informed about why ambiguity poses such problems for young children. Instead, I questioned whether children's problems with ambiguity are as far reaching as is supposed or whether they might succeed on tasks which offered them different strategies to handle ambiguity and I tried to strip away aspects of ambiguity tasks, other than this holding in mind, in the hope that I will build a better picture of the child's abilities and difficulties.

In summary, I use the concept of EF as a tool, hence the description a functional application. No one theoretical approach is deemed most appropriate to inform my thinking about ambiguity, but the literature identifies several questions and concepts, which are of great use, perhaps most importantly the possibility of performance errors and the notion of planning and goal-directed behaviour. The concept of EF offers an opportunity to tease apart what we might mean by understanding or handling ambiguity, which is not immediately

apparent within the communication or theory of mind approaches, but vital to my discussion of handling ambiguity as an information processing problem. Whether this work on ambiguity might feed back into thinking about EF remains open.

## 5 Introduction to Experimental Work

Thus far, I have considered two broad areas of research: children's understanding of ambiguity and more generally, the executive function literature. In the previous section I have sought to explain how the latter informs my approach to the current research. In this section I return to the issues raised by the ambiguity literature and describe how these, in combination with the EF approach, ground the current experimental work.

A starting point is my concern that the established literature is dominated by verbal and reflective tasks. Children were frequently asked to judge whether they knew a referent or whether messages were good. I have claimed that adults rarely evaluate messages explicitly and they use a variety of strategies, which means such tests are too limited to tap children's abilities fully. I have also observed that disordered executive functions in adults can lead to a counterintuitive split between the ability to use a strategy and report on it, and that a parallel divide between implicit and explicit abilities are the focus of much attention in developmental psychology. I have argued from these observations that the verbal and evaluative tasks alone cannot tell us whether young children have the competence to handle ambiguity. Hence, my experiments are behavioural, rather than verbal, and I have endeavoured to keep the child's possible responses directed to attaining the goal of the game (say, identifying which picture is on a card) rather than make a separate and abstract evaluation of knowledge or message. Ackerman et al (1990) noted a need for further research of children's understanding of ambiguity in context. I take this on board, using games with clear goals through which the child's abilities can be teased apart. In an entirely naturalistic



setting we might only see children's preferences for particular strategies, without furthering our knowledge of their understanding (see my criticisms of Speer, 1984, above) and so I have used games in which I can see whether they have other skills or strategies available.

Although I have criticised the work that suggests children's choices when confronted by ambiguity are systematic (Speer, 1984; Jackson & Jacobs, 1982), claiming it reveals little about their understanding, it is important to recognise that these experiments do address what children do when they are forced to deal with ambiguous input. Even very young children do in their everyday lives cope with ambiguity without hitting any serious problems (van Hekken, Vergeer, & Harris, 1980). I adopt this strategy in my experiments, but manipulate the responses children can make, such that they inform us about children's understanding of why ambiguous input is problematic. In my experiments, children can make an interpretation of ambiguous input or seek new information (Experiments 3 and 5) or delay their interpretation (6 and 7). In particular, I introduce a novel procedure (in Experiment 3) that I use to test whether children's use of such strategies is systematic.

I suggested that previous work that directed children to ask questions if they were not sure of the answer might not have revealed the true scope of children's abilities to handle ambiguity. Although children are competent, even excessive, question users in everyday life, they do not ask appropriate questions to disambiguate ambiguous input. I claim that from their failure to do this, it is difficult to argue that children don't understand ambiguity. Children's failure to ask questions to disambiguate ambiguous input cannot tell us for certain that children do not understand what to do in response to ambiguity. Children may have difficulty translating their good understanding of the problem into a question. If this were the case then we may have to think of this as a separation between children's implicit and explicit abilities to handle ambiguity, or as a performance error masking competence. It will

become clear as I accumulate data that these are not distinctions I will need to make. I claim that there are steps prior to making a response which also need consideration, before concluding that children do not understand how to handle ambiguous input. These include identification of potential referents and of the information which will resolve the ambiguity, selection of the most appropriate strategy (guess or actively or passively disambiguate) and translation of your knowledge about what you need to know into your chosen strategy. I note here that although the term is tempting to use, the idea of “understanding” ambiguity is not especially useful to this work. Exploring only the end point of making a final response to ambiguous information ignores these possible subcomponents and makes it difficult if not impossible to identify any fledging skills the child might have. I will return to this in Chapter 4, when I move from tests which explore children’s use of strategies to deal with ambiguity, to examine other skills. These skills alone would not be considered as revealing understanding of ambiguity, but they do help me narrow where the child’s problems with these ‘end point’ strategies might stem from.

To clarify my use in this thesis of the phrase “handling ambiguity” rather than “understanding ambiguity”, it is useful at this point to consider what performance we would accept as revealing understanding of ambiguity, and indeed, to identify where problems with this phrase might lie. We could demand that the child shows a fully verbalisable understanding of the problem: that s/he is able to describe the message as problematic because it is ambiguous, can explain why this is and suggest and justify a course of action to resolve the ambiguity. For example, if there are two red toys , a truck and a ball, on the table and the child hears an ambiguous message “The toy I’ve chosen is red” a verbal response showing this type of understanding might be, “I can’t tell which toy is meant, because the message does not give sufficient information to choose between the truck and the ball. With

more information I could choose between them.” Perhaps the response might even include “You need to tell me if it’s the truck or the ball” or “I will guess it’s the ball, but it might be the truck.” However, I have argued that it might be precisely these problems with verbalising one’s knowledge which prove difficult for young children. Furthermore, such a measure of understanding is an exceptionally strict one, more so than typical developmental tests of “understanding” in other areas (e.g. the classic false belief task).

Instead, I have focussed on children’s ability to use strategies effectively to handle ambiguous input. In the current research children will be described as being able to handle ambiguity if they employ strategies such as seeking new information or making tentative interpretations to discriminate ambiguous from unambiguous input. To return to my earlier discussion of the implicit/explicit distinction success on such a task, but without the ability to describe the process verbally may fail some definitions of explicit understanding. However, I suggest that choice of strategies would involve decision making processes such that we would be unwise to relegate it entirely as ‘implicit understanding’.

A further difficulty arising from attempts to fit the notion of implicit and explicit understanding to ambiguity is what we might identify as ‘implicit understanding’. For example, as described in section 1.1, Plumert (1996) found that children showed longer reaction times to ambiguous rather than unambiguous messages. This is a candidate for ‘implicit understanding of ambiguity’. As I discussed above, the term can be used in this way to suppose that the ‘implicit understanding’ is like ‘explicit understanding’ only inaccessible. I suggest that it is unnecessary to propose that a child who shows longer reaction times to ambiguous stimuli holds ‘implicit understanding of ambiguity’. Children’s performance on Plumert’s task could be the result of children responding to uncertainty caused by certain messages, without any notion of why this uncertainty has arisen. Indeed, this is a possibility I

will investigate in my thesis. Thus, rather than think of the differences in nonverbal behaviour as showing ‘implicit understanding’, they might equally well be showing an ability to respond to uncertainty.

In my investigation of whether children can handle ambiguity, only appropriate purposeful selection of strategies will be taken as evidence that the child has his ability. I will also investigate subcomponent skills in later chapters. However, success on these subcomponent tasks would not reveal a partial understanding of ambiguity, but rather competence in a skill which is necessary to handle ambiguity. I believe that describing success on a subcomponent task as ‘partial understanding of ambiguity’ is possibly too generous. It would imply that children had some understanding of what it means for an input to be ambiguous or what would be the appropriate response to such information. In my exploration of children’s ability to handle ambiguity, we will see that despite success on some tasks, attributing such an understanding might not be justified. I note, as an interesting aside, that if we were to find evidence that children could use some strategies but not others to handle ambiguity, then we may have grounds to ascribe a partial understanding of ambiguity to the child.

The experimental work in this thesis is arranged in four chapters. The experiments evolve from the findings of earlier ones and so the theoretical justification for the experiments will be developed as the thesis progresses. Broadly however, the first experimental chapter (Chapter 2) explores whether children might be using an acceptable strategy to respond to the ambiguous messages of previous research, but one which adults consider inappropriate in this situation. That is, are they making tentative interpretations which they know are based on insufficient information and may be incorrect? In Chapter 3, I explore the possibility of performance errors. I ask children, rather than to respond to

ambiguous messages, to evaluate inappropriate responses with hindsight. This type of reflection is concerned with what might have been an appropriate strategy and remains within the context of the goal of resolving the ambiguity. I believe this contrasts with earlier tasks in which children had to distance themselves from their task of handling an ambiguous input and reflect and evaluate their current state of knowledge. I also introduce the idea of risk in this chapter and investigate whether children might fail ambiguity tasks because they don't see the problem as important enough to warrant great consideration or a cautious strategy. In Chapter 4, I focus on certainty rather than uncertainty. I explore whether children find it easier to act when they know rather than when they do not. Finally, in Chapter 5, I examine a narrow aspect of handling ambiguity, that of identifying the information which differentiates potential referents. Through the course of these experiments I move from the possibility that children might have the competency to employ alternative strategies to handle ambiguity, to suggesting that it is exactly this problem of working out what to do about ambiguous input that leads to such poor performance on ambiguity tasks.

In summary, I have drawn on two literatures: the development of understanding about ambiguity and the executive function research, to justify my approach. I question the conclusions drawn on the basis of the referential communication literature; that base the claim that children have difficulty understanding ambiguity on their failing of evaluative, verbal tasks. In Chapters 2 and 3, I attempt to facilitate children's use of alternative behavioural strategies. In Chapters 4 and 5, I explore two of these 'subcomponent' skills: identifying disambiguating information and recognising certainty. By the end of the thesis, I aim to have both extended our understanding of how children handle ambiguous input and offered a more precise account of what their difficulties might be.

## **Chapter 2: Are Children's Interpretations of Ambiguous Messages**

### **Tentative?**

The experiments in this chapter form the basis for a paper, Beck and Robinson (2001) published in the *Journal of Experimental Child Psychology*.

In the introduction to this thesis I have discussed the claims that children have difficulty responding to ambiguous input. They tend to make interpretations of such input and do not ask questions which would disambiguate the information they have, allowing them to make a better informed interpretation. In this chapter I consider a possible explanation for this, in which the root of the child's failure is not a misunderstanding of ambiguity, but the adoption of an idiosyncratic strategy, unexpected by the experimenters. In everyday life, one reasonable adult response to ambiguity is to make a tentative interpretation of the information, holding the alternative possibilities in mind. Although it is widely believed that young children have difficulty understanding ambiguity, it is possible that when they make interpretations of ambiguous input, they are aware of their tentative nature. Indeed, this possibility has been suggested by Speer (1984), who proposed that if children could not use saliency clues to identify a referent as the intended one, they would use a guessing strategy. That is, they would pick one potential referent, but hold this as tentative until they were or were not corrected. In Chapter 1, section 3.2, I have criticised his evidence for this, claiming that children who did not understand what is problematic with an ambiguous message might appear to be using this strategy. Yet there remains a need to ascertain whether the interpretations children make of ambiguous inputs are tentative.

I have also suggested that attempts to probe children's confidence in their interpretations, using "Do you know...?" questions or asking them to rate their confidence

are limited to telling us only what children can explicitly report about their state of knowledge. It adds a stage on to the process of handling ambiguity which increases the demands of the child's task and is not a normal part of the process. In this chapter I explore whether children treat their interpretations as if they are tentative, without asking them to evaluate them. I begin with a simple test of whether children might treat their interpretations as tentative: are they more likely to revise their interpretations of ambiguous messages than they are informative ones?

## 1 Experiment 1: A comparison of children's willingness to revise their interpretations with their knowledge evaluations

I modified a procedure devised by Robinson, Champion and Mitchell (1999) to assess children's ability to discriminate between informed and un-informed speakers. In the original procedure the child either saw or guessed the content of a container, was contradicted by an adult speaker who was either guessing or informed, and finally the child had the opportunity to revise or repeat his/her original interpretation. Three- and 4- year olds were more inclined to revise their original suggestion when the speaker was better informed than they. In that procedure, the relatively ignorant partner saw nothing of the container's content (though knew what the possible contents were), and the relatively informed partner saw the entire content. In our experiments, I was interested in how older children would deal with partial information. As in the original procedure, children experienced a sequence of two inputs, but this time they were both messages. After hearing the second message, children had the opportunity to revise their initial interpretation. I used willingness to revise as an indicator of lack of confidence in their initial interpretation. Would children be more likely to revise interpretations based on ambiguous versus informative messages? Willingness to revise

under the conditions just described (the “behavioural group”) was compared to performance by a second group of children (the “know group”), who were asked to make verbal evaluations of their knowledge following their initial interpretation of the first message on each trial. I further investigated children’s responses to different types of ambiguous messages: those which were helpful in that they allowed them to narrow the range of referents (in this experiment from four to two) and those which were useless, giving no information about the intended referent. Throughout this thesis, I will refer to the former as narrowing clues and the latter as uninformative. Informative is used to describe clues which identify only one referent. Children might be less willing to revise their interpretations of the former type of message than the latter, and more inclined to judge that they really know, simply because the narrowing message enabled them to reduce the set of possible referents.

## **1.1 Method**

*Participants.* I tested 37 children from an infant school serving a predominantly working class population in Birmingham, U.K. Data from 3 children were excluded due to experimenter error, leaving 14 girls and 20 boys with a mean age of 5 years and 8 months (5;8), range 5;3 to 6;2. Children were systematically allocated to either a behavioural group (18 children) or to a know group (16 children).

*Materials.* I used 10 A4 sheets, each with four pictures, one sheet for each trial. For example, one picture set showed a brown monkey, brown squirrel, black and white rabbit, and black and white cow. Clues for this picture set were “It’s an animal” (uninformative – referred to any of the 4 pictures), “It’s black and white” or “It’s brown” (narrowing – referred to 2 pictures) and “It says moo” or “It’s got a fluffy tail” (informative – refers to only 1 picture). In addition, I used a pack of cards, each of which showed one of the pictures. On each trial the experimenter held one card, to ensure that the child realised that both clues in a



trial referred to the same picture. I also used a video cassette in its case and a plain cardboard box, measuring approximately 20cm x 10 cm x 2cm for the ignorance check trials.

*Procedure.* Apart from the first 6 children tested (see below), each child began with 2 ignorance check trials. All children then had 2 warm-up trials, followed by 8 experimental trials. The purpose of the ignorance check trials was to check whether children would evaluate themselves as ignorant in at least some circumstances. Children were first shown a video tape box. The experimenter said: “We’ll look inside this box in a minute, but first, can you just tell me, do you really know what’s in this box or don’t you really know?” Children were expected to say that they did know what this box contained. They were then shown an unfamiliar box (the plain cardboard box), to see whether they would admit ignorance as to its content. After answering each knowledge question, the child was shown the content of the box, a video tape in its box and a crayon in the unfamiliar box. No other feedback was given.

Children then entered either the behavioural or the know procedure. The procedure for children in the behavioural group follows. On each of the 2 warm-up trials the child was shown one of the picture sheets and asked to name the four pictures. The child was then told: “I’ve got a card here with one of these pictures on it. I’m going to tell you about the picture and let’s see if you can work out which one it is. I’ll tell you two things about the picture and sometimes you’ll be able to work out straightaway which one I’ve got and sometimes you’ll want to change your mind.” In the first warm-up trial children were told “It’s blue” and were then asked “So which one do you think it is?” Since only one object pictured was blue (a balloon with a long string) I expected children to choose correctly and confidently. Immediately after they had chosen a picture they were told “I’ll tell you something else about this picture: It’s got a long string.” and were then asked “So which one is it?” After they had responded children were shown the picture on the card held by the experimenter who said

“See, that time it was the balloon, so you knew straightaway, didn’t you?” On the second warm-up trial children saw an orange shirt, orange scarf, purple trousers and purple hat. They were given the clue “You can wear it”, followed by a disambiguating clue which was inconsistent with their chosen object: “You wear it on your head/legs”. Children were also given feedback on this trial “So that time it was the hat/trousers, so you wanted to change your mind, didn’t you?” The appropriate responses were explained to children regardless of their response. Four of the 18 children in the behavioural group wrongly changed their interpretation following the second clue in the first warm-up trial.

The remaining eight trials were the experimental trials. Children continued to see sets of four pictures, but received no feedback on the correctness of their responses. Instead they were told that they would see all the chosen pictures together at the end of the game. Children had two trials each of four types of trial: An uninformative clue followed by a narrowing one (uninformative – narrowing); uninformative – informative; narrowing – informative and informative – uninformative. Both the uninformative and the narrowing clues were ambiguous. An example of each trial type is given in Table 1. Trials were presented in four orders chosen so that each trial occurred in the first, second, third and fourth position. The same sequence of trials was presented twice to produce a total of eight trials. The order of the pictures used was systematically varied, using five predetermined orders. For all trial types except informative – uninformative the experimenter gave second clues that contradicted the child’s interpretation. Thus, on trials where the first clue was uninformative or narrowing, I ensured that the child’s first interpretation was incorrect. The informative – uninformative trials were included to check that children did not revise their suggestion as to the intended referent simply because a second clue was given.

**Table 1: Trials used in Experiment 1**

Trial type	First clue	Second clue	Appropriate response
uninformative – narrowing	It's an animal (chooses monkey)	It's black and white	CHANGE to cow or rabbit
uninformative – Informative	It's an animal (chooses monkey)	It goes moo	CHANGE to cow
narrowing – informative	It's black and white (chooses rabbit)	It goes moo	CHANGE to cow
informative – uninformative	It goes moo (chooses cow)	It's an animal	STICK with cow

At the end of the game children were shown all the pictures that had been chosen and were encouraged to identify which ones they remembered, to give the game a satisfactory ending. The experimenter used sleight of hand to ensure that the cards the child saw at the end were consistent with the clues given.

Children in the know group were warned on the first warm-up trial: “Sometimes you’ll really know which picture I’ve got and sometimes you won’t really know.” On every trial, having made an interpretation following the first clue, children were asked “Do you really know it’s that one or don’t you really know?” The feedback given on warm-up trials was “So that time it was the balloon, so you really knew didn’t you?” and “So that time, it was the hat, so you didn’t really know, did you?” Seven children out of 16 in the know group wrongly said they knew the correct referent on the second warm-up trial. However, as children were then shown the actual referent, which contradicted their choice, these trials were useful in making it absolutely clear to the children that there were occasions on which they could guess the wrong picture.

The experimental trials for 11 of the children in the know group were the same as for the behavioural group: uninformative – narrowing, uninformative – informative, narrowing – informative and informative – uninformative. After hearing the first clue the child was asked to evaluate his/her knowledge by responding to the test question “Do you really know it’s that one or don’t you really know?” Following an uninformative or narrowing clue it was appropriate to acknowledge ignorance, “I don’t know” and following an informative clue it was appropriate to say “I do know”. These children also heard the second clue after their knowledge judgment and were given the chance to revise their interpretation.

The remaining five children in the know group, those in the one message subgroup, were run under a more conservative procedure. These children did not hear the second clue and had no opportunity to revise their interpretation. This sub-group was run to check whether being allowed to revise their interpretation influenced children’s answers to “Do you know?” However, early results confirmed (i) that even with the possible learning opportunity available to the main two message know group, children’s knowledge judgments were inaccurate, and (ii) there was no hint that knowledge judgments under the two procedures were different from each other. Therefore, the majority of children had the two message procedure described above, to give them, if anything, the better chance of learning to make accurate knowledge judgments. Data from both procedures were pooled for comparisons with the behavioural group.

## **1.2 Results and Discussion**

Ignorance check trials. The first six children tested were not given these trials due to experimenter error. These children were split equally between the know and behavioural groups. Their data were included since all gave one or more correct “don’t know” responses in the experimental trials and so clearly were willing to acknowledge ignorance. Of the 28

children who were given both ignorance check trials, 26 responded “don’t know” on at least one of them and so were willing to acknowledge ignorance at least under some conditions. Unexpectedly, many children responded in this way to the video box, apparently because they did not know which particular video it contained.

Experimental trials. Children in the behavioural group were given a score of 1 every time they updated their initial choice to be consistent with the second message, and 0 every time they repeated their original choice. (On two occasions children changed to a second picture that was inconsistent with the second message, and these were given scores of 0.) Scores for each of two similar trials were summed to give each child a set of four scores each out of 2. Children in the know group were given a score of 1 every time they judged “No I don’t know” and 0 every time they judged “Yes I do know”. The children in the one message sub-group heard only the first clue for each of their 8 trials, but for the purpose of making comparisons with the behavioural group, their knowledge judgments can be considered as arising from each of the trial types which the rest of the children in the knowledge group experienced.

On the narrowing – informative, uninformative – narrowing, and uninformative – informative trials, adult-like behaviour is indicated by a score of 2 for each set of trials. For the informative – uninformative trials adult-like behaviour is indicated by a score of 0.

Judgments on the knowledge trials were in line with the previous literature: Children generally acknowledged correctly that they did know following informative messages (only one child claimed not to know) but there was a strong tendency to over-estimate the knowledge gained from uninformative and narrowing messages. The mean numbers of “don’t know” responses for each trial, with confidence intervals, are shown in Table 2. A repeated measures ANOVA, with trial type as a within-subject variable, revealed a significant within-

subject effect of trial,  $F(df=3,45) = 7.58, p < .001$ . From examination of the confidence intervals it can be seen that there is no difference between the responses to the trials that began with narrowing or uninformative clues. However, the confidence intervals for responses to the trials that began with informative clues did not overlap with those of the other trial types. Children were discriminating between message types, being more likely to say “don’t know” following uninformative or narrowing messages than following informative ones, but their performance overall was far from ceiling.

**Table 2: Mean number of appropriate responses in Experiment 1**

Trial <sup>a</sup>	Mean don't know responses for know group. Max. = 2 (95% confidence intervals in brackets)	Mean change responses for behavioural group. Max. = 2 (95% C.I.)
narrowing – informative	0.56 (0.23 – 0.90)	1.83 (1.64 – 2.02)
uninformative – narrowing	0.75 (0.30 – 1.21)	1.83 (1.64 – 2.02)
uninformative – informative	0.94 (0.48 – 1.39)	2.00 ceiling performance
informative – uninformative	0.06 (-0.01 – 0.20)	0.33 (0.01 – 0.68)

<sup>a</sup> The second clue is heard by behavioural group and by the two message subgroup of the know group. The one message subgroup heard only the first clue.

Performance by children in the behavioural group was impressive. Their mean responses are also shown in Table 2 with confidence intervals. Importantly, 14 of the 18 children correctly repeated their initial suggestion on both informative – uninformative trials, so they were not merely revising following any second message. Yet 13 out of 18 always

revised their interpretation appropriately on uninformative – informative, narrowing – informative and uninformative – narrowing trials. Using a repeated measures ANOVA with trial type as the within-subject variable, I again found a significant difference in responses to the different trials,  $F(df=3,51) = 66.00, p < .001$ , and examination of the confidence intervals shows no difference in performance on narrowing – informative and uninformative – narrowing trials. Performance on the uninformative – informative trials surpassed this, as the children performed at ceiling. Again, comparing responses to the informative – uninformative trials with those for the ambiguous trials for which there are confidence intervals, there appear to be differences. Children in the behavioural group were less likely to change their interpretation following the second message on the informative trials than on the ambiguous ones. They were behaving as if they understood the relative weights that could be placed on their interpretations.

Although children in both groups discriminated the trials in which it was appropriate to change their interpretation or say “don’t know” from those in which they should stick with the original interpretation or say “do know”, performance by the behavioural group looked considerably better. To check this statistically I classified children according to their individual strategies across the eight trials. Fourteen of the 18 children in the behavioural group (78%) used an appropriate strategy on all trials or on all but one trial, but only 2 of the 16 in the know group (12.5%) achieved this level of performance, a significant difference in favour of the behavioural group:  $\chi^2(df=1)=14.49, p < .001$ .

Interestingly, there was no difference in either the behavioural or the know group in children’s responses to uninformative and narrowing clues. They seem not to have assumed (wrongly) that having made some, rather than no, exclusions on the basis of a narrowing clue, they could be more certain of the intended referent.

Children in the know group who were given a second clue after they had made their knowledge judgments, performed very well in response to the second clue despite their over-estimation of the knowledge gained from uninformative and narrowing clues. Of the 11 children in this group, all performed at ceiling or made only one mistake on the behavioural responses, but only two made no or one mistake in response to the knowledge questions. That is, many children said that they really knew the intended referent of an uninformative or narrowing clue but then correctly revised their interpretation in the light of the subsequent informative clue.

The behavioural responses of the 5- and 6- year olds in this experiment are consistent with the possibility that they could make genuinely tentative interpretations following ambiguous messages, and could revise these in the light of subsequent information. If so, then their explicit knowledge judgments would seem seriously to under-estimate their understanding of the informativeness of ambiguous input. However, this could be a generous interpretation of what these children were doing. One alternative possibility is that children initially detected a problem in interpreting the ambiguous input, but having gone on to make an interpretation they did not hold that as tentative but believed that they really knew the intended referent. On hearing the second message they may then have recalled the original state of affairs (both the clue and the possible referents), and with hindsight recognised the need to revise their original interpretation. If this were the case, then the initial interpretation would not be held as tentative, and the child would be dependent on the provision of further information to prompt appropriate behaviour. The explicit judgment “I really know” would be a genuine reflection of the child’s evaluation of knowledge prior to the receipt of the second contradicting message.



Yet another possibility is that children made an interpretation and believed that they really knew that it was the intended referent, but on hearing the second contradicting message did not recollect accurately the earlier state of affairs, and so had no way of integrating the two inputs. For such children the situation would be like one in which they received a sequence of informative but contradicting messages. In order to resolve this contradiction, children may have abandoned their first interpretation and made a second in line with the second input.

The main aim of my second experiment was to try to exclude this last possibility: On hearing the second piece of information, were children just making a second, independent interpretation rather than revising their original interpretation?

## 2 Experiment 2: Are children's reinterpretations of ambiguous messages revisions or restarts?

I used the same procedure as for the behavioural group in the first experiment, but used new sets of pictures, which allowed for a new trial type. In this narrowing – disambiguating trial type the first clue could refer to two of the four pictures (A or B), and the second clue in isolation also referred to two of the four pictures (B or C). Taking the two clues together, B could be identified as the correct referent. If children's initial choice in response to the first clue was A, I was interested in what choice was made following the second clue. Children who were equally likely to select either referent of the second clue (B or C) could have made a confident interpretation of the first ambiguous clue, failed to understand (even with hindsight) that it could be revised, and so made an independent interpretation of the second clue (the last possibility suggested in Section 1.2 above). On the other hand, children who consistently revised their interpretation to choose the picture that

was consistent with both clues (B) would appear to understand that their interpretation of the first ambiguous clue could be inaccurate and were prepared to revise it on hearing the second.

## **2.1 Method**

*Participants.* I tested 38 children from a primary school serving a predominantly lower middle class population in Birmingham, U.K. Data from 1 child was excluded due to experimenter error, leaving 8 girls and 29 boys in the final sample (this was a result of the gender imbalance of the year group in the school), with a mean age of 6 years and 2 months (6;2), range 5;9 to 6;8.

*Materials.* I again used A4 sheets with four pictures on each. There were two sets of pictures for the warm-up trials and six sets for the experimental trials. On experimental trials, children were shown one of four sheets, each using a different layout of the pictures (e.g. clockwise from top left: Car, train, plane, helicopter in one layout; helicopter, plane, train, car in another). As before, a pack of picture cards was used for the experimenter to hold.

*Procedure.* The game was introduced as in Experiment 1, with two warm-up trials followed by six experimental trials. There was no need for ignorance check trials since children did not make explicit knowledge judgments in this experiment. On presentation of each sheet of pictures, children were asked to identify which of the pictures corresponded to the two clues they would hear. For example, if the messages were to be “It’s orange” and “It goes in the air”, they identified which of the pictures were orange and which were purple and which travelled in the air and which on the ground before hearing any clues about the experimenter’s chosen picture. The experimenter talked them through this initial identification, prompting with “Are there any more?” to ensure that they always identified all the possible referents. This was included in the procedure to reduce the chance of children

making confident initial interpretations because they failed to notice the other possible referents.

There were three types of experimental trials and each child had two trials of each type, presented in a counterbalanced order. Clues were either informative or narrowing as in Experiment 1, or disambiguating, as described above. Trial types were: narrowing followed by informative; informative – narrowing; narrowing – disambiguating. Examples of these trials are shown in Table 3. The informative – narrowing trials were included so children did not always have to update their initial interpretation; my main interest was in the comparison between the other two kinds of trials. Order of presentation of the sets of pictures and of the arrangement of the pictures on the sheets were systematically varied, using four different arrangements of the pictures on the sheets and five different orders of presentation of the sets of pictures themselves.

**Table 3: Trials used in Experiment 2**

Trial type	First clue	Second clue	Appropriate response
informative – narrowing	It's got a flower on it (chooses train)	It goes on the ground	STICK with train
narrowing – informative	It's orange (chooses train)	It's got a star on it	CHANGE to helicopter
narrowing – disambiguating	It's orange (chooses train)	It goes in the air	CHANGE to helicopter

## 2.2 Results and Discussion

Children's responses were coded as correct when they chose a second picture that was consistent with both clues. Simply scoring children as repeating or updating their initial responses (as in Experiment 1) would not capture correct behaviour on narrowing –

disambiguating trials. On these trials children had to change to the picture which was identified by the two clues in combination. On narrowing – informative trials, children were correct if they changed to the single picture identified by the second clue. On the informative – narrowing trials, they were correct if they restated their original choice.

Performance on the informative – narrowing trials was important, as in Experiment 1, to confirm that children did not change to a new interpretation merely because they heard a second clue. Children performed reasonably well on these trials: 29 of the 37 children never changed their interpretation when an informative clue was followed by a narrowing one, and the mean score was 1.68 out of a maximum of 2 (95% confidence intervals 1.453 – 1.899). Four children wrongly changed on one trial and four did so on both trials. In all cases these errors consisted of selecting a picture that was consistent with the second clue but not the first.

Having confirmed that most children resisted changing their interpretation when the initial clue was informative, my interest was in children's performance on the narrowing – disambiguating trials. Children performed well: 35 of the 37 children always selected the picture that was consistent with both messages, and the remaining two made a single error by selecting a picture which was consistent with the second message only. The mean score was 1.95 out of a maximum of 2 (95% confidence intervals 1.870 – 2.022). This is close to the ceiling performance of the children on the narrowing – informative trials (mean score 2.0). A one sample t test to compare performance on the narrowing – disambiguating trials with a mean score of 2 (ceiling performance) revealed no significant difference between the narrowing – disambiguating scores and this ceiling score:  $t(df = 36) = -1.43, p = .16$ . The power of this test is relatively low (.29), but the data provide no grounds for suggesting that on narrowing – disambiguating trials children made an interpretation of the second message

alone. As mentioned above, 35 out of the 37 children answered correctly on all ambiguous trials. An impressive 28 children (76%) obtained perfect scores on all trials: always changing to the right picture on the ambiguous trials and always repeating their first choice on the informative – narrowing trials. For simplicity and because of the importance that children did not just change their interpretation on the narrowing – disambiguating trials, as described above, I have not recoded the data behaviourally as in Experiment 1 to check that children were discriminating between the trials where they should stick and those where they should change. However, it is clear from the generally excellent performance on this task, that children were making the right responses to the different trials.

It is possible that, coincidentally, children found the correct referent more attractive or salient than the other. To check, I compared the initial choice made when a particular clue occurred first (on narrowing – informative trials), with the choice made in response to that same message when it occurred second (on narrowing – disambiguating trials). I inspected the data for all 6 clues that occurred in both positions. In every case when the narrowing clues came first the choices were split between the two potential referents, but when the same clue was a disambiguating one, children chose the potential referent that was also consistent with the first clue. The differences in distribution were significant by binomial tests for four of the six sets; for the remaining two sets the sample sizes were too small to test statistically. This suggests that selections of the appropriate referent on the narrowing – disambiguating trials were not an artefact caused by children's preferences for one of the two potential referents.

The results of Experiment 2 go beyond the results of the first experiment in showing that children were genuinely revising their interpretations of the ambiguous clues and were not simply making an independent interpretation of the second clue. The results from the

narrowing – disambiguating trials also address a second issue. Merely tagging an interpretation based on ambiguous input as ‘uncertain’ would be insufficient for appropriate future revision. That is, without remembering the original message or set of potential referents, the child would not know how new information should be used to update an original uncertain interpretation. Using the example with which I introduced this experiment, the first message potentially refers to A or B and the child chooses A, tagging it as uncertain. S/he then hears the second message which potentially refers to B or C. If s/he reasons that this new information contradicts the choice of A, but cannot recall either the set of referents of the first message, nor the message itself, s/he has no information to decide between B and C. Children’s systematic choices in this experiment on narrowing – disambiguating trials allow me to conclude that children are not only tagging their first interpretation as uncertain but are using source monitoring skills to combine the two messages.

In so far as they made genuine revisions of the first ambiguous clue, rather than abandoning it, the 5- and 6- year old children treated their initial interpretations of the ambiguous clues as tentative. They behaved as if they understood that the interpretation was subject to revision in the light of subsequent information and they were able to recall (or reconstruct using the original message) the original set of potential referents. Why then did the children in the know condition of the first experiment so often judge that they really knew the intended referent of an ambiguous clue? As suggested in the discussion of Experiment 1, children could have been confident in their initial interpretation until the second, contradicting, clue was received. This contradiction may have prompted them to re-construct the circumstances under which the original interpretation was made, and then make an appropriate revision to their interpretation. In the final experiment in this chapter, I explored an implication of this possibility.

### 3 Experiment 3: Can children seek information to increase the accuracy of an interpretation? The Cones Procedure.

We know from the results of Experiments 1 and 2 that children could treat their interpretation of an ambiguous clue as tentative when subsequent contradicting information was offered to them, but what if the onus was on them to gather the information? In Experiment 3, I investigated whether children would seek additional information to increase the accuracy of their interpretation of an ambiguous clue. To try to make things easy, children were not required to seek information to revise an interpretation already made and to which they might feel committed. Rather, they had the opportunity either to make an immediate interpretation of a clue or to use a very simple strategy to gather additional information. If children used these two strategies appropriately following ambiguous and unambiguous clues, this would be consistent with their realising without external prompting that an interpretation of ambiguous input could be wrong.

As I have summarised in the introduction, previous research suggests that young children tend not to seek clarifying information. In this new procedure I avoided the concern that children's abilities might be masked by difficulties indicating "can't tell" by either verbal or non-verbal means (see e.g. Markman, 1977; Patterson & Kister, 1981; Robinson, 1981). Although I noted that a problem judging "can't tell" seemed unlikely to be the main cause of children's problems in Chapter 1, Section 3.1, I was keen to give the children the best chance possible of success. More importantly I also wanted to avoid the problem that seeking information in these tasks is not directed to the goal of resolving the ambiguity. One problem which might lead to children failing to make a "can't tell" response or asking a disambiguating question, is that they may be unable to resist making an interpretation. I

discuss this possibility in the light of the results of this experiment and it leads us to the experiments in Chapter 3.

In this new procedure I provided a very simple information seeking response (lifting a cone to see what was beneath), which was similar to the interpreting response (placing a doll in front of a cone). In addition, in contrast to responding to an ambiguous utterance with an evaluative “can’t tell”, in this procedure, obtaining the missing information enabled the child to complete the task correctly. I also tested an older group of children on this procedure, to ensure that successful performance would be seen at an age when children are reported to behave appropriately with regard to single ambiguous utterances (e.g. Bearison & Levey, 1977; Sodian, 1988), although as mentioned in the introduction, older children still make errors on ambiguity tasks under some circumstances (see e.g. Asher, 1976; Flavell, Green, & Flavell, 1985; Keil, 1980).

### **3.1 Method**

*Participants.* I tested 26 5- to 6- year old children (mean age 6;0 range 5;7 – 6;6) and 30 7- to 8- year old children (mean age 8;0, range 7;5 – 8;5). The children were from a primary school in Reading, UK, serving a working and middle class population. There were 14 boys and 12 girls in the younger sample and 16 boys and 14 girls in the older sample.

*Materials.* For each trial I used three 10cm tall paper cones coloured either pink, green, yellow or blue. A large cardboard box was used to hide the cones from the child. A small plastic doll, 6 toys belonging to the doll (hat, bucket etc.) and a small mat (approx. 10cm<sup>2</sup>) were also used.

*Procedure.* The child was introduced to a doll called Peter and a set of his toys, which the child was encouraged to name. The doll was seated on a mat on one side of the table and three paper cones were placed on the other side of the table, both within reach of the child.



The game began with two warm-up trials, the purpose of which was to familiarise the child with the two possible ways of responding to a message – by selecting a referent immediately or by lifting a cone to gain further information. The experimenter explained that she was going to hide Peter's toys from him and the child's task was to help Peter find them. In the first warm-up trial the cones were all the same colour. A box was used to screen the cones from the child's view and one of the toys was hidden under one of the cones. The experimenter said, "I've hidden the x [name of hidden toy] under one of these cones. I'll tell you what colour it's under. It's blue." The experimenter then talked the child through the appropriate response: "They're all blue, so this time you need to look under the cones before you move Peter" and the child was encouraged to look under the cones. In the second warm-up trial all the cones were of different colours. In this trial the experimenter explained: "This time you could find the right cone straightaway, so you didn't need to look under them, you could just move Peter to sit by the (yellow) cone." The two strategies were then summarised: "Sometimes you have to pick up the cones when you can't find the right one straightaway and sometimes you don't have to pick them up, when you can find the right one straightaway."

Following the warm-up trials, there were four experimental trials. In these, there were always two cones of one colour and one of a different colour. Clues were either ambiguous, referring to either one of two cones the same colour, or informative, identifying the uniquely coloured cone. Each child had two ambiguous trials and two informative trials. Half the children had the ambiguous trials first, and the others began with the informative trials. Since children would inevitably receive feedback about the location of the toy if they chose to pick up the cones, at the end of each trial all the cones were lifted up together to reveal the toy's location, although no comment was made on the appropriateness of their choice of strategy.

### 3.2 Results and Discussion

I was interested in whether children discriminated between the ambiguous and the informative clues by being more likely to pick up a cone following an ambiguous clue, and more likely to move the doll following an informative clue. Children received two scores of 0, 1 or 2, according to the number of times they picked up the cones on ambiguous and on informative trials. Frequencies and mean responses for each age group are shown in Table 4.

**Table 4: Frequency of looking under cones in Experiment 3**

		Frequency of looking under cones			Mean responses (max = 2)
		0	1	2	
5-6 year olds	ambiguous	5	9	12	1.27
	informative	11	6	9	0.92
7-8 year olds	ambiguous	2	3	25	1.77
	Informative	20	6	4	0.47

Scores were entered into a repeated measures ANOVA with trial type (informative or ambiguous) as a within-subject factor, and age (younger or older group) and order (ambiguous or informative trial first) as between-subject factors. There was a main effect of trial type: Children were more likely to pick up the cones in response to the ambiguous messages than they were in response to the informative messages,  $F(df=1,52) = 47.86, p < .001$  and there was a significant interaction between task type and age,  $F(1,52) = 16.07, p < .001$ . No other effects were significant.

The interaction between age and task type arose because the difference between tasks was significant only for the older children: Using a separate ANOVA for each age group,

with trial type (ambiguous or informative messages) as a within-subject variable and order as a between-subject variable, there was a significant difference in performance on the two tasks for the 7- to 8- year olds,  $F(df=1,28) = 66.13, p < .001$  but not for the 5- to 6- year olds,  $F(df=1,24) = 3.83, p = .062$ . For the younger children, the test was sensitive to large effects ( $\eta^2 = .14$ ), so it is possible that a larger sample would demonstrate discrimination between trial types for the younger children. Within this sample, only the older children were more likely to pick up cones in response to the ambiguous messages than to the informative ones.

Children's individual response patterns over trials were in line with the results of the above analysis. Sixteen of the 30 children in the older age group (53%) showed the appropriate pattern, always raising a cone when the clue was ambiguous and always moving the doll when the clue was informative, compared with only 4 of the 26 children in the younger group (15%):  $\chi^2(df=1) = 8.74, p = .003$ . Of those who failed to show the appropriate pattern across trials, 7 of the younger children always picked up a cone, 4 never did, and the remaining 11 showed some other pattern of responding. The corresponding frequencies for the older group were 4, 1 and 9. Importantly, many of the younger children used both the interpreting and the seeking strategies, but unlike the older children they apparently failed to understand the circumstances under which each strategy was appropriate. Not only did the children who failed the cones task use a mix of the two strategies, but there was no clear bias in the children who failed to choose an appropriate strategy to favour always looking under the cones or always moving the doll. This is of particular interest because work on children's inhibition skills has shown that up the age of about 6, children may have difficulty inhibiting prepotent responses. Indeed in one task 4 year old children had difficulty inhibiting a response to look in a well, even though children of the same age succeeded on a verbal condition of the task, indicating that they understood the task requirements (Livesey and

Morgan, 1991). Of the children who failed my cones task 5 children never looked, 8 looked on 1 trial, 4 looked on 2 trials, 8 looked on 3 trials, and 11 looked on 4 trials. There was a slight trend towards looking (the 11 children looking on all 4 trials compared to 5 children who never looked), but the distribution of children categorised by how often they looked was no difference from chance using a Chi Square test. Given this indiscriminate use of both strategies, it cannot be argued that children who might really understand about ambiguity, nevertheless chose one of the cones, because they assumed implicitly that this is expected of them, or that any errors would be corrected (e.g. Speer, 1984).

To check that the younger children really had difficulty with this simple task, they were also categorised by strategy. Each child was allowed to make one mistake, so in other words I gave them the benefit of the doubt by grouping children who chose the appropriate response on three trials with the perfect strategy users. This measure of success will be referred to later in the thesis as the “adjusted strategy”. 8 (31%) of the younger children were now categorised as correct adjusted strategy users, whereas 24 (80%) of the older children did so. This was significantly different  $\chi^2(df=1)=13.78, p<.001$ .

I compared this performance against chance. I include a probability tree illustrating the chance of correct performance on this task in Appendix A. The chance of making three out of four correct responses is 5/16. From the sample of 26 children in the younger group, we would expect 7.5 adjusted correct strategy users. Clearly, the younger children’s performance was no better than chance. We would have expected 9.4 of the 30 children in the older group to be using a correct adjusted strategy by chance. The number of children observed is much higher than this (24) and the observed distribution is significantly different to chance,  $\chi^2(df=1)=33.02, p<.001$ . Although this comparison only supports my claim that the younger children perform poorly on this procedure rather than being necessary to it, I

have included it for consistency as comparisons against chance will be used in later experiments.

#### 4 Discussion of Experiments 1-3 and Summary

The starting point for this chapter was the possibility that the interpretations that children make of ambiguous messages may in fact be tentative ones that they are able to treat as such. Consistent with the established literature, the 5- to 6- year olds in Experiment 1 tended to over-estimate the knowledge they gained from ambiguous clues. However, I found that young children could nevertheless deal effectively with ambiguity under certain limited conditions. In Experiments 1 and 2, 5- to 6- year olds could treat their interpretations of ambiguous information as if they were tentative. That is, they revised their original interpretations of ambiguous messages on hearing new disambiguating and contradicting information, but generally did not revise their interpretations of unambiguous messages. In these experiments I had removed the demands of generating an appropriate response to ambiguity, and instead the child's handling of ambiguity was scaffolded by the procedure.

Although the children's behaviour in Experiments 1 and 2 is what we would expect if they were making genuinely tentative interpretations, in Experiment 3, using the cones procedure, the 5- to 6- year olds had more difficulty. When their choice was either to seek new information or make an interpretation, very few of them responded correctly. Their pattern of strategy use contrasted with that of the 7- to 8- year olds. Yet if the younger children had realised that their interpretation of an ambiguous message was as likely to be wrong as right (the message had two potential referents), surely they would have taken the simple step of lifting a cone to check?

How can we reconcile this discrepancy in performance between Experiments 1 and 2 on the one hand, and Experiment 3 on the other? Could the 5- to 6- year olds be making

tentative interpretations when they first heard ambiguous messages? Following Experiment 1, I suggested three possible explanations for children's behaviour. Firstly, children who act as if they are making a tentative interpretation may indeed genuinely be holding in mind the two alternatives from the beginning. Or secondly, they might be making a confident interpretation of the information, which they only treat as tentative with hindsight when they encounter the contradiction. The third explanation was that children might be making new interpretations based only on the second clue, but this possibility was ruled out by Experiment 2. The results of Experiment 3 encourage us to reject the first description of the child's behaviour. The procedure in Experiment 3 gave children the opportunity to seek disambiguating information before making an interpretation. I reasoned that if an interpretation of ambiguous input is tentative, then the child should use a strategy to seek information that allows conclusive identification of the referent. Although the older children often used the seeking strategy appropriately, the younger children generally did not. This suggests that at the time of making their initial interpretation they did not treat it as tentative; that is, as an interpretation that would benefit from disambiguating information. Furthermore, performance on the evaluative "know" judgments in Experiment 1 can support the alternative proposal. Children asserted that they really knew the intended referent of the ambiguous messages. One possibility is that their difficulty here lay simply in making explicit verbal judgments. However, my results are more consistent with the possibility that they really were confident in their interpretations of the ambiguous messages, and it was not until they had the contradicting information imposed on them that they called on their source monitoring skills to reconstruct the original events and resolve appropriately the contradiction that they now experienced. It is particularly interesting to note the behaviour of the children in the know group of Experiment 1 who said that they really knew the intended referent of an ambiguous

clue but then revised their interpretation correctly on hearing new information. Thus far my results suggest that when the 5- to 6- year olds in my experiments made interpretations of ambiguous information they were confident in them until those interpretations were contradicted.

An alternative explanation must be considered, and this will introduce the experiments to be presented in Chapter 3. It is possible that even though children know that an interpretation they make is a guess and another referent is equally likely to be correct, they are unable to resist making an interpretation. Based on the executive function literature, I characterise this as a performance error, an inability to inhibit the response of making an interpretation. There are at least three reasons why we might suspect this is not the case:

- 1) in the cones procedure in Experiment 3, the younger children, who were judged as performing poorly, did not show a bias towards making interpretations, but instead only 7 (32%) of the 22 children who did not use an appropriate combination of the two strategies consistently chose a cone.
- 2) if children made an interpretation in spite of the opportunity to seek disambiguating information, yet understood that it was a guess, their answers to the “Do you know...?” questions might be expected to reveal this awareness. In Experiment 1 we saw no evidence of this, even when children made know judgements in the two-message subgroup who had had their interpretations corrected by contradicting information and revised them appropriately.
- 3) it is questionable whether making an interpretation can be thought of as a prepotent response, which the child finds difficult (or impossible) to inhibit. However, it may be that young children learn to make interpretations or guesses in response to any information they can and so the possibility that children are thwarted by a prepotent

response to make an interpretation rather than disambiguate the message they hear remains open.

Despite these suspicions, it is prudent to explore the possibility that young children's competence is being masked by a performance error and in Chapter 3 I address this.



### **Chapter 3: The Possibility of Performance Errors**

In Chapter 2, we saw that although children performed well when they had to treat their interpretations of ambiguous messages as if they were tentative, they did not choose (in Experiment 3) to seek disambiguating information before making an interpretation. This was particularly striking, as the majority of children did use the seeking response (looking under the cones) on some trials, but not systematically. I suggested that this meant that children's interpretations are not tentative at the time they make them. Otherwise, it would only be sensible to seek the readily available extra information that would improve the accuracy of the interpretation. However, I identified an alternative possibility. Children might recognise that the message has multiple potential referents and realise that extra information (in this case looking under the cones) would increase the accuracy of their interpretation, but fail to do so because of a performance error: they fail to seek disambiguating information appropriately because they cannot resist making an interpretation. I made several observations that support my first suggestion rather than the performance error possibility, but recognised that firm evidence was needed before this possibility could be ruled out. To address this, I present two experiments in this chapter that reduce the inhibitory demands for the child.

If children are unable to inhibit making a response when this option is available to them, one way of removing this problem is to ask the child to think about possible strategies with hindsight (see Jacques et al, 1999). In the experiments in this chapter, children were not asked to choose between seeking and interpreting on hearing an ambiguous message, instead they observed another's actions. When an ambiguous message was interpreted too early, an undesirable outcome ensued and the child was asked to consider "What should [the person] have done?" By doing this, the child is required to generate a counterfactual alternative to the

events that s/he has witnessed. Not only does this new retrospective task remove the problem of inhibiting an immediate interpretation but there is also evidence from the literature on counterfactual reasoning that suggests that children's performance might improve under these circumstances.

Roese (1997) has discussed the functional role of counterfactual reasoning. He suggested that although generating counterfactuals in response to negative events causes short term disadvantage, by way of negative affect while one is focussed on the event, it is beneficial in the long term because one can think of alternative strategies for the future. In everyday life, people generate upward counterfactuals (which postulate a better alternative world than the real world) more often than downward counterfactuals (in which the alternative world is worse) (Roese & Olson, 1997). Importantly, Roese claims that 'cognitive responses, such as narrowed attention and heightened systematic thinking are "mobilized" in response to negative affect' (p135) (citing Taylor, 1991). From this I reasoned that on seeing an undesirable outcome arise because someone makes an overconfident interpretation of an ambiguous message, one would be prompted to generate a preferable counterfactual alternative. Although it is contentious whether very young children (3- and 4- yr olds) can reason counterfactually (see Harris, German & Mills 1996; Riggs, Peterson, Robinson, & Mitchell, 1998; Robinson & Beck, 2000; Sobel, 2001), by the age of 5 children can generate counterfactuals (German, 1999). In line with my reasoning, the 5 year olds in German's study generated counterfactuals in response to negative outcomes, rather than positive ones. If the child understands that an alternative strategy is more appropriate than making an interpretation, then using a counterfactual (and necessarily retrospective) question gives them an excellent chance to reveal this competence.

I present two experiments in this chapter, which used counterfactual questions. In the first, Experiment 4, children heard stories about characters who made hasty interpretations of ambiguous messages. In Experiment 5, I attempted to increase any effect of counterfactual reasoning skills by involving the children themselves in the outcome, using a modified version of the cones task.

## 1 Experiment 4: Resolving ambiguity in stories with hindsight

### 1.1 Method

Children entered into one of two groups: a retrospective group who were asked what the story characters should have done in response to messages, after the interpretation had been made and its consequences observed, and a prospective group who were asked what the character should do at the point at which s/he heard the messages.

*Participants.* I tested 43 5- and 6- year olds and 43 6- and 7- year olds from an infant school serving a predominantly lower middle class population in Birmingham, UK. Data from 9 younger and 2 older children were excluded. 7 younger children made inappropriate choices which could not make sense within the story: 6 of them choose an inappropriate referent on informative trials (3 from each group) and one chose the already rejected option on an ambiguous trial (from the retrospective group). The difficulties children might have had with these stories are considered in the discussion. One older child was excluded as he offered an appropriate alternative strategy in response to an ambiguous message, but chose an alternative referent under forced choice. Three children (2 younger, 1 older) were excluded due to experimenter error. This left 19 girls and 15 boys in the younger sample with a mean age of 5 years and 9 months (5;9) range 5;3 to 6;2 and 19 girls and 22 boys in the older sample with a mean age of 6 years and 10 months (6;10) range 6;4 to 7;3.

*Materials.* Stories were told to the children by the experimenter using picture cards (approx. 20cm x 10cm). At the point where the child was asked to choose a strategy (on hearing the ambiguous message for the prospective group, or after hearing the consequences of an inappropriate interpretation for the retrospective group) the child was shown four pictures simultaneously, giving them a forced choice of strategies.

*Procedure.* Children were told that they would hear some stories and see pictures on a set of cards. Each child heard four stories, two of which included an ambiguous message, two an informative message. Ambiguous messages in this experiment were uninformative, in that they did not narrow the set of potential referents. Ambiguous and informative trials alternated and the type of first trial (ambiguous or informative) was counterbalanced between children. The order in which the stories were presented was systematically varied using four fixed orders, and the presentation of the fixed choice options was varied by the experimenter. Scripts for the four stories are included at Appendix B. In each story the child was introduced to a central character who was asked by an adult character to perform a task using a message that was either ambiguous or informative. For example in one story, John was asked by his mum to take a book upstairs to his granny. There were three, differently coloured books on a table and so mum's ambiguous message was "It's on the table", whereas her informative message was "It's green."

For the retrospective group, after the character heard the message, s/he made an interpretation of it. On ambiguous trials the character chose one of the potential referents, and so in this example John was shown holding one book and then giving the book to his unhappy granny, who said, "That's not my book." The experimenter said, "So John's taken the wrong book." In the informative trials, the character mistakenly took a referent that did not match the message. So again, granny was given the wrong book. For this group the

experimenter said “Let’s think back, when mum said, “Can you take granny’s book upstairs. It’s on the table/It’s green.” There were different things that John could have done.” Children were presented with four choices: “He could have taken the red book upstairs, he could have taken the blue book upstairs, he could have taken the green book upstairs or he could have asked mum something else about the book.” (The order of the choices varied so that the ‘ask’ strategy was not always suggested last). Three potential referents were used, rather than just two, so that when a choice had been identified as incorrect it was still not possible to deduce which was the correct referent. Otherwise, choosing to take the other referent would have been sensible. As each choice was listed, a picture illustrating the choice was placed on the table in front of the child, so that s/he had a set of four pictures from which to make his/her forced choice. The test question used was “What should he have done?” Children who chose the referent that had already been identified as incorrect on ambiguous trials, or an incorrect referent on informative trials, were excluded as noted in the participants section.

For the prospective group, the same four choices were presented to the child at the point in the story when the ambiguous message was heard. The child was shown the same set of pictures as were the retrospective group. In ambiguous trials, where the clue did not allow the child to make an accurate interpretation, if the child chose the “ask” picture, mum told John the colour of the book. He took the correct book to granny, who was seen in a final picture to be pleased. If the child chose one of the other pictures, that is made an interpretation, s/he was shown John giving the book to an unhappy granny who explained, “That’s not my book. My book’s red/green.” contradicting the child’s choice. In informative trials if the child chose “ask”, s/he was told an extra redundant piece of information and then allowed to choose a referent to complete the story. If the child chose the correct referent s/he

saw granny looking happy, receiving the correct book, who said “Thank you very much, that’s my book.” The children who chose an inappropriate referent were excluded.

## 1.2 Results and Discussion

Responses were scored according to the child’s behaviour. They scored 1 for choosing ‘ask’ and 0 for choosing either of the alternative potential referents on ambiguous trials, or the correct referent on informative trials. This represents appropriate behaviour in the ambiguous trials, but inappropriate in informative trials.

I ran a repeated measures ANOVA with trial (ambiguous or informative) as the within-subject variable and age (younger (5- and 6- year olds) or older (6- and 7- year olds)), timing (prospective or retrospective) and order (ambiguous or informative trial first) as between-subject variables.

There was no main effect of order, nor any interactions that included order. There was a significant effect of trial,  $F(df=1,67)=37.164, p<.001$ . Mean responses are shown in Table 5. Children were more likely to choose ‘ask’ in response to ambiguous messages than to informative messages. Overall, the group of children were discriminating the two types of message, but as is seen in Table 5, their performance is far from ceiling.

**Table 5: Mean responses (scores between 0 and 2, scored for tendency to say "ask")**

	Prospective		Retrospective	
	ambiguous	informative	ambiguous	informative
year 1	0.856	0.328	0.722	0.222
year 2	1.273	0.636	1.328	0.644

There was also a significant effect of age,  $F(df=1, 67)=6.319, p=.014$ . There were no other significant effects, nor interactions. Most importantly, there were no effects of timing. Thus, the older children were simply more likely to choose ‘ask’ overall, they were not more likely to choose this strategy in the retrospective trials, nor were they better discriminators than the younger children. This is as we would expect because even the older children are younger than the literature would predict success for on ambiguity tasks.

The results give no indication that the timing of the test question “What should he do/have done?” affected children’s performance. My suggestion was that children’s performance might be improved due to both the removal of the inhibitory demands of making an interpretation and because they might be prompted to generate a counterfactual following the undesirable event. In this case their difficulties would be best conceived of as a performance problem. Children did not find it easier to discriminate ambiguous from informative messages when they considered them with hindsight and thus, we have no evidence to support this possibility. It seems that an inability to resist making an interpretation cannot explain children’s difficulty with ambiguity. However, before I concluded that this was the case, I considered an alternative explanation of the results from this experiment.

Roese and Olson (1995) suggested that adults will be more likely to engage in counterfactual thinking when they are personally involved in an outcome. By being involved an individual is more likely to experience negative affect when the outcome is undesirable, prompting them to consider counterfactual alternatives. In Experiment 4 children were not personally involved in the situations, instead they heard a story and they might not have considered the outcomes particularly bad – in all the stories the ‘bad outcomes’ could be easily rectified. In my follow up experiment, I used what I hoped would be a much more

serious event for the child – not gaining a token which they needed to win a sticker.

Importantly, this outcome could not easily be rectified and so I hoped would be viewed as more serious by the child. Furthermore, several children were excluded from Experiment 4 for giving nonsensical answers. It might have been that children did not pay sufficient attention to the stories because they were too complicated or because they did not find them sufficiently engaging. A change in procedure to one in which the child is personally involved and which is relatively simple (there are only two response options in Experiment 5, a modified version of the cones game from Experiment 3, rather than four in the stories task and the events leading up to the response are fewer) should both reduce information processing demands and increase the likelihood of spontaneous counterfactual reasoning.

## 2 Experiment 5: Does personal involvement improve performance on a counterfactual ambiguity task?

### 2.1 Introduction

Although evidence from Experiments 3 and 4 does not support the possibility that children have a problem inhibiting a response to ambiguous messages, I ran a second experiment using a modified version of the cones procedure from Experiment 3, to confirm this. I hoped that children had a greater incentive to generate a counterfactual alternative, as they were personally involved and I introduced an element of risk, in the hope that the outcome on the retrospective trials would be seen by the child as an undesirable outcome. I also increased the number of potential referents of ambiguous messages; there were four same coloured or same patterned cups under which the target could be hidden. These changes should give the children more incentive to perform to their best in the trials (due to increased



risk) and make the inadequacy of an ambiguous message even more obvious (due to a larger number of potential referents).

## 2.2 Method

*Participants.* I tested 40 5- and 6- year olds and 28 4- and 5- year olds from an infant and junior school serving a predominantly lower middle class population in Birmingham, UK. Data from two older children were excluded as they did not complete all the trials, leaving 21 girls and 17 boys with a mean age of 6 years and 2 months (6;2), range 5;10 to 6;8 in the older group and 13 girls and 15 boys with a mean age of 5 years and 3 months (5;3) range 4;10 to 5;9 in the younger group.

*Materials.* I used plastic cups coloured red, green, blue or purple or patterned with stripes or spots. Patterned cups were either red or blue. In addition, I used 2cm<sup>2</sup> paper stars, a orange cardboard arrow (approx. 10cm long), a large cardboard box to screen the cups from the child's view during hiding and a teddy bear glove puppet (Bobby the bear). Animal stickers were offered as an incentive for winning the game.

*Procedure.* The child was told that s/he would be playing a hide and seek game and in the game stars would be hidden underneath the plastic cups. The child's task was to find as many of the stars as possible. If s/he won more stars than the experimenter did then s/he would be rewarded by a sticker. All of the children appeared keen to try to win a sticker. The experimenter introduced the puppet, Bobby the bear, and explained that he was going to try to help the child win lots of stars.

As in Experiment 3, there were two warm-up trials in which the experimenter talked the child through the two possible strategies s/he could use in the game. The child was informed that sometimes s/he would be able to find the right cup straightaway, but sometimes s/he would not. If the child could find the right cup straightaway s/he was to move the pointer

straight to the right cup, but if s/he could not find it, s/he could have a look underneath the cups first, before moving the pointer. In the first warm-up trial, three cups of different colours were used. While the cups were hidden from the child's view using the box, the experimenter hid a star under one of them. Having removed the box, so the child could see the cups, the experimenter gave the child a clue, "I've hidden the star under one of these cups, I'll tell you something about it, it's blue." The experimenter then explained that as there was only one blue cup, the child could move the pointer straightaway and did not need to look underneath them first. The child was then encouraged to move the pointer. On the second warm-up trial, three same-coloured cups (e.g. green) were used. Having hidden a star the experimenter gave an ambiguous message, "I've hidden the star under one of these cups, I'll tell you something about it, it's green" In this case the experimenter explained that as all the cups were the same colour the child could not find the right cup straightaway and would need to look first. The child was then encouraged to do this.

The remaining five trials were experimental trials. Each child participated in two types of ambiguous trials, those in which the child him/herself was able to act on the ambiguous message, child trials, and those in which the puppet acted and the child answered a counterfactual question about his performance, puppet trials. The order of the trials was alternated and the first trial was counterbalanced between children. Ambiguous trials fell in two blocks, each of one puppet and one child trial. The third trial (after one of each type of ambiguous trial) was an informative trial. The cups used for each block were differentiated either by colour or by pattern. The order of coloured or patterned blocks was counterbalanced. The unambiguous trial always used different coloured cups.

In Child Trials the procedure was similar to the warm-up trials, except that there were four cups of one colour and one of another (or four of one pattern and one of another) and

the experimenter gave no instruction as to the correct strategy. Instead, immediately after the child heard the message, s/he was asked “What do you want to do, move the pointer or look first?” (the order of the two strategies was counterbalanced). The child’s response was recorded. If the child found the star, after looking or moving the pointer immediately, s/he kept it, but if s/he moved the pointer to the wrong cup the experimenter got to keep the star.

In Puppet Trials the same number of cups was used and the experimenter gave the puppet the choice of the two strategies. The puppet always chose to move the pointer and did so to a possible but incorrect cup. The cup was lifted up to show that it did not hide the star and the experimenter said “Oh no! Bobby moved the pointer to the wrong one, so you don’t get the star this time. Let’s think, what should he have done, moved the pointer somewhere else, or looked first?” Again, the order of the two strategies was counterbalanced.

Informative Trials were the same as Child Trials, except that the message identified the unique cup in the array. On these trials it was appropriate to move the pointer straightaway as there was no need to look first.

At the end of the five experimental trials, the game ended if the child had won more stars than the experimenter had. In this case, they were asked to count the stars and were allowed to choose a sticker as reward. Alternatively, more informative trials were used to allow the child to gain sufficient stars to beat the experimenter. Thus, all children appeared to win the game and received a sticker.

### **2.3 Results and Discussion**

Children were scored as either moving the pointer (scored 1) or looking (0) on Child Trials and Informative Trials and as saying “Moved the pointer” or “looking” on Puppet Trials (Table 6). On the Informative Trials, 27 (71%) of the older group and 13 (46%) of the younger group made the appropriate response, moving the pointer without looking.

**Table 6: Performance on ambiguous trials in Experiment 5**

			Puppet trials		
			0	1	2
Younger group 4-5 yr olds	Child trials	0	2	0	0
		1	1	5	1
		2	1	4	14
Older group 5-6 yr olds	Child trials	0	0	2	0
		1	0	0	5
		2	0	7	24

From the table, performance on the ambiguous trials looked good. Indeed 24 (63%) of the older group and 14 (50%) of the younger group performed perfectly on the ambiguous trials. The difference between the groups was not significant using a Chi Square test. I compared performance on puppet trials and child trials using 2-tailed binomial tests for the two groups (comparing only perfect performers with non-perfect). There was no significant difference between the types of trials for either age group: there was 1 child in the younger group who performed perfectly on puppet trials but not on child, and 6 who showed the reverse,  $N=6, k=1, p=0.218$ ; there were 7 children in the older group who were perfect on the puppet trials but not on child and 7 who showed the reverse pattern  $N=14, k=7, p>.999$ . From this there is no evidence that children find the counterfactual (or puppet) trials easier than the standard trials, which is consistent with my findings in Experiment 4.

Although we have no reason to think from these results that the counterfactual task is easier than the standard task, children do appear to be performing well on both (child and puppet) ambiguity tasks here. There were two changes to the standard cones procedure made in the child trials: firstly, I used a larger number of potential referents (4 instead of 2) and

secondly I introduced an element of risk, a disincentive for guessing too early. Could either of these changes have caused an improvement in children's performance? I compared children's performance on this modified procedure with that of the younger group tested in Experiment 3, the standard cones procedure. I made this comparison to see if there was any indication that these children were performing unusually well on this task, although I recognised that conclusions would need to be tentative, as different samples were compared. I did not compare performance with the successful older group as I wanted to confirm whether the children in this experiment performed better than those who had performed poorly on the cones procedure before. It was clear in Experiment 3 that children were flexible in using the strategies available to them, but the real test of their ability was whether they systematically employed each strategy when appropriate. Thus, to decide whether children are performing well on an ambiguity task in this experiment, it is important to consider the children's responses to informative trials as well as their responses to ambiguous trials. I identified the children in this experiment who had used the appropriate response on both child trials and on the single informative trial. To reduce the length of the procedure and because my main concern in this experiment was the comparison of child and puppet trials I included only one informative trial in this procedure, rather than two, as in Experiment 3. So, rather than use the categorisation of individuals from that analysis, I identified children from Experiment 3 who answered both ambiguous trials correctly and the first of their informative trials. As each child is only assessed on three trials now and the informative trial response is judged vital to the child's success, I used a strict test of performance, only counting children who got all three trials correct and not allowing any errors. These results are shown in Table 7.

**Table 7: Comparison of overall strategy use between Experiment 3 and Experiment 5**

	Performance on ambiguous trials and sole/first informative trial	
	Incorrect	Correct (look on both ambiguous trials, choose on informative)
Exp. 3 younger group	21	5
Exp. 5 younger group	21	7
Exp. 5 older group	16	22

Using Chi Squared tests I found no difference in performance between the younger group in this task and the children in Experiment 3,  $\chi^2(df=1)=0.26, p=.610$ . Despite the problems of comparing between two separate samples of children, the performance by the two younger groups is convincingly similar, indeed almost identical. The apparently good performance by the younger children on the ambiguity trials is misleading as it is not backed up by discriminating performance on the informative trials. Note, also that there is no difference between the number of children in each experiment answering their (first) informative trial correctly (13 (46%) younger children in this experiment made an immediate interpretation, 13 (50%) did so in Experiment 3). There was a significant difference between the performance of the Experiment 3 children and the older children in this sample,  $\chi^2(df=1)=9.46, p=.002$ . The children in this experiment were tested near the end of the school year and the majority of the older group were already 6, so it is likely that these children are performing well on this procedure because they are old enough to cope with ambiguity. Despite the attempt to increase motivation (through adding an element of risk and increasing the number of potential referents), there was apparently no improvement in the younger children's performance. However, I acknowledge that it is possible that such a procedure

might reveal better performance for children who are in the process of mastering these strategies and developing understanding (perhaps the older children in this sample).

Increasing risk might help children to concentrate on the task in hand and might not only reveal early signs of understanding, but it is also possible that such situations might be critical in the child's learning about ambiguous input. Clearly these are speculations and I continue to focus on why young children have such difficulty with ambiguous input in my following experiments. I return to the effect of risk on the child's performance in Experiment 7 and question whether increased risk necessarily improves performance.

Finally, as it seems that the children in this experiment found the task no easier than my previous sample in Experiment 3, the absence of any effect of the type of trial (whether the child actively participates, or troubleshoots the puppet's behaviour) offers more evidence against the possibility that being unable to resist making an interpretation is at the root of the young child's difficulty with ambiguity.

### 3 Discussion of Experiments 4 and 5 and Summary

At the beginning of this chapter, I introduced the possibility that children might fail ambiguity tasks because they were unable to resist making a response. I identified three factors which I tackled in these experiments: that the child might be unable to resist making a prepotent response (making an interpretation because s/he can), that a negative outcome might prompt the child to reconsider the event and generate a counterfactual alternative and that extra cognitive resources would be dedicated to this counterfactual thinking which would improve the child's chance of identifying an appropriate response strategy.

In Experiment 4, I used a simple procedure in which children heard stories in both prospective and retrospective (counterfactual) conditions. They were given a forced choice of four responses, making one of the three possible interpretations or asking an adult for more

information. I found no evidence that children chose the appropriate “ask” strategy more often with hindsight than prospectively, and hence, no support for the proposal that the child’s difficulty was in avoiding making a response. Interestingly, the older group of children (6- to 7- year olds), who also performed poorly on the task, were more likely to choose to ask for information than the younger group of children. Yet, they were no more likely than the younger children were to discriminate the informative or ambiguous trials. Possibly, the older group, who had been at school longer and perhaps had learnt more about communication in general, were more likely to see merit in the ‘ask’ response. In the General Discussion I will consider the findings from several of my experiments, which show children adopting different strategies to respond to ambiguous information, despite not revealing competence in understanding how to handle such input appropriately.

To confirm my results from Experiment 4, I ran a second counterfactual experiment. Based on the adult literature I changed the procedure to make the child more involved in the events and make the outcome more negative from the child’s point of view. I still found no support for the proposal that the child’s performance would improve when the inhibitory demands of standard prospective tasks were removed.

In Experiment 5, I tested an older group of children who performed very well on the task overall. Performance by the younger group did not match this and appeared statistically no better than the performance of the younger children in Experiment 3 (although my tests compared different samples, so any conclusions must be relatively cautious). I concluded that the older group’s success is most likely due to their maturity. The younger children who are performing poorly on the standard, child trials, found the counterfactual puppet trials no easier. Furthermore, although there was no statistical difference in the older group’s performance on the two types of trial, this was undoubtedly influenced by the small number



of children making any mistakes. If anything, there was a trend towards better performance on child trials rather than puppet. Rather than facilitating the child's handling of ambiguity, the added memory demands and imaginative components (generating a specific alternative world) may have made this task more difficult.

The results from Experiments 4 and 5 confirm the suspicions raised at the end of Chapter 2 that children were not making performance errors. In Experiment 3 children used a mix of the strategies available, rather than persistently making interpretations as would be expected if the performance error explanation was correct. I also noted that it could be difficult (but possible) to conceive of making an interpretation as a prepotent response. Finally, these results are consistent with children's tendency to judge that they know the intended referent in knowledge evaluation tasks.

In Chapters 2 and 3, I have made attempts to expose children's ability to handle ambiguity by exploring their use of practical behavioural strategies. We have seen that, despite their ability to use a seeking response and revise their interpretations of ambiguous input, children's use of these strategies offers no evidence that they are able to handle ambiguity competently. In the later experimental chapters, 4 and 5, I look at children's understanding of the information available to them, but remove the demands of actively choosing a strategy. It is possible that when these demands of choosing a strategy are removed, children will succeed. Children's understanding about the ambiguity of the input might be good, but they might be unable to translate this into appropriate action. Alternatively, their problems might extend to understanding why the information itself is problematic. I elaborate on this shift from focussing on strategy selection in more detail in Chapter 4.

## **Chapter 4: Knowing When You Know**

### **1 Introduction: A move from strategy selection**

In Experiments 1-5, I investigated whether children could use simple behavioural strategies appropriately to handle ambiguity. Although there is much evidence that children have difficulty with verbal and evaluative tests of their understanding of ambiguity, the evidence from their non-verbal behaviour (eye movements, response latencies etc. (see e.g. Patterson et al., 1980, Plumert, 1996)) gave us reason to consider at least the possibility that children's competence was not revealed by these evaluation tasks. Children might have had difficulty with the verbal demands of the tasks, either formulating specific questions or making reflective explicit evaluations of knowledge and messages. Also, the types of strategy offered in the established literature were limited. These might not be responses which children find easy, appealing or think are appropriate to use.

I have found no evidence from my tasks that children can employ the simple behavioural strategies I offered to handle ambiguity. In Experiments 1 and 2, I found a promising result that children were able to revise their interpretations of ambiguous messages. Furthermore, they did this in such a way that they used the original message, rather than restarting their interpretation process on correction (Experiment 2). This suggested that children might be making tentative interpretations of ambiguous input. However, the results of Experiments 3, 4 and 5, are more supportive of an alternative explanation – that children's interpretations were not tentative at the time they made them.

There are two paths of future action open. I could persist in trying to simplify and change my ambiguity tasks in the hope that I would find a behavioural strategy that young children can use successfully. Alternatively, I could tentatively conclude that children have

genuine problems employing both verbal and behavioural strategies to handle ambiguity, and move to explore more closely what children reveal about their understanding of ambiguous input when I remove the demands of selecting a strategy.

I have taken the second path – for two main reasons: firstly, I felt my tasks were already very simple and children have shown, in all the experiments thus far, that they were able use the responses offered to them (revising interpretations, seeking information by looking under the cones and saying “ask” (the older children in Experiment 4)), without revealing any signs of competence in understanding about ambiguity. Secondly, I have increased our knowledge about what children can and cannot do when confronted by ambiguity: their ability to revise interpretations suggests that their abilities are well adapted to everyday encounters with ambiguous information, and I confirmed that their difficulties are not due to a performance error, as they can resist making an interpretation. My research approach in Chapters 4 and 5 will inform any future attempt to identify strategies they can use.

I drew on my reading of the executive function literature to frame this move away from strategy selection. In the experiments that follow, I removed the aspect of planning an appropriate strategy to resolve the problem one faces. The idea that planning might be a central aspect of executive function is accepted by many researchers, even if definitions of what constitutes “planning” are often vague (see e.g. Burgess et al, 1998; Welsh et al., 1991; although Duncan, Emslie, & Williams, 1996 have moved away from thinking of dysexecutive patients as having problems with “planning” and developed the notion of “goal neglect”). I wanted to know how much of the processing of information, that would be necessary to inform a final planning decision, could be achieved by the child. If the child has difficulty with these more basic processes then it is premature to ask him/her to select a

strategy, as the problematic aspects of the ambiguous input would not have been recognised or analysed. However, if the child succeeded on the component processes, then I might be well placed to claim that they fail ambiguity tasks because of difficulty with the planning aspects of handling ambiguity. I do not think it is necessary to imagine that in dealing with an ambiguous message, one needs to go through these stages as a linear chain of processes. It might be that a problem in planning what you are doing is so bound up in understanding why you are doing it, that within the context of an ambiguity task, you cannot undertake the subcomponents. In the next two chapters I attempted to use new procedures, in which the child has little to do in terms of planning, to explore whether I might tease apart which components of this larger process of handling ambiguity they might have particular difficulty with or indeed might find easy (out of context).

I identified two skills that I thought should enable one to use the responses in my ambiguity tasks systematically:

- 1) knowing when to seek extra information, i.e. you need to know when you do and do not know there is only one certain referent.
- 2) knowing what you can find out to differentiate the referents.

Certainly it is logically possible to understand 1 without 2: you realise that you are uncertain but don't know what will disambiguate the message (for example, if two things appear to be identical and there is no obvious source of disambiguating information). But the reverse is also conceivable. The child might have a specific comprehension monitoring problem – that s/he cannot identify whether s/he can be certain or not, but would be able to identify how the potential referents differ. For example, confronted by the message “It's black and white” on my pictures task, when the set includes a black and white rabbit and a black and white cow, the child might recognise that the pictures differ because one is a cow

and one a rabbit, so s/he could find out more about what kind of animal it is, but might mistakenly think that she can really know that the intended referent is the rabbit – that having some information does allow one to make an interpretation.

So the important move in Chapters 4 and 5 is an attempt to remove the need to plan an appropriate way to deal with ambiguity from the child's task and investigate children's success on tasks which tested the component skills I had identified. In Experiments 6, 7 and 8, I explored what children might understand about the limitations of ambiguous information. This might allow me to identify the child's difficulties as being the result of quite a specific problem, such as comprehension monitoring or identifying disambiguating information, or might lead me to think that although the child could succeed on the subcomponents of the task of handling ambiguous information effectively, s/he is unable to respond appropriately because of a problem planning an appropriate strategy.

In Chapter 4, I addressed the first of these subcomponent skills, moving to the second in Chapter 5. As in the pictures task from Chapter 2, the procedure was scaffolded for the child. I did not ask the child to decide what to do in response to ambiguous input, but instead only to act when s/he was able to make an interpretation. S/he did not have to choose actively whether extra information was needed, but instead was presented with a stream of information. The child had only to make a response when there was sufficient information to make an accurate interpretation, i.e. when s/he knew which was the intended target. My aim was to see whether a difficulty identifying when you are certain or uncertain (which we might think of as a very basic and restricted comprehension monitoring problem) might be at the root of children's problems identifying appropriate strategies to use. This would also provide a simple explanation of why children have such difficulty with the verbal, evaluative tasks used extensively in past research.

## 2 Experiment 6: Knowing when you know and the effect of risk

### 2.1 Introduction

I explored whether young children, who had performed so poorly on my other behavioural ambiguity tasks, would succeed when I removed both the need for strategy selection (planning what to do) and for identification of useful information. In the stopping information game, the child saw a picture revealed in stages, from underneath doors on a piece of card. These doors were opened at steady (and quite slow) intervals. The child had a set of pictures to choose from and s/he had to identify which picture was on the card. My aim was to remove the requirement to respond actively to the ambiguous information. Instead, given my success showing that children were not failing ambiguity tasks due to problems inhibiting a response (Chapter 3), I asked the child to wait until s/he knew which one it was. I hoped that providing a continuous flow of information would give the child the opportunity to reveal good certainty monitoring skills, which might be more difficult for him/her to use when evaluating an isolated piece of inadequate information, perhaps because that evaluation is tied up with trying to plan what to do. If the child succeeded on this task, then s/he is making the right response to the ambiguous input, implicitly, by not making an interpretation based on it. However, it would be critically important that such behaviour was seen on a task in which the goal and planning demands were changed so radically from a classic ambiguity task.

I compared performance between two groups of children: a risk group and a speed group. My reasoning was that children have a tendency to make interpretations of ambiguous information too early (even though I have shown that this is not always the case, see Experiments 3 and 5) and so I expected that children would be quite likely to make a guess

once they had seen a small part of the picture. I gave the second group greater incentive to wait until they were certain which of the pictures was on the card – by making the normal reward for playing the game (a sticker), dependent on the child identifying the majority of the pictures.

## **2.2 Method**

*Participants.* I tested 42 children from an infant school serving a predominantly working and middle class population in Birmingham, UK. There were 18 girls and 24 boys with a mean age of 6 years and 5 months (6;5), range 5;11 – 6;10. Children were systematically allocated to either a risk group (22 children) or to a speed group (20 children).

*Materials.* I used four picture cards (approx. 15cm by 10cm). A cardboard cover over the pictures had five doors cut into it, which allowed sections of the picture to be revealed. On the three picture cards used in experimental trials (a bus, a cup and a lady) three of the doors revealed an uninformative section of the picture (i.e. it could equally well be part of any of the pictures), one revealed a narrowing section (it could be a part of two of the pictures) and one door revealed a disambiguating or informative section (true of only one of the pictures). In the warm-up trials (a snowman), four doors revealed uninformative sections, and one a disambiguating section. On each trial children had a sheet of paper (20cm x 15cm) with four pictures on it. These were four similar items that differed on one key feature (e.g. four buses with different coloured doors) and on experimental trials also differed on a second partially informative feature (e.g. two buses had orange wheels, two had blue wheels). A rubber stamp and ink pad was used by the child to indicate his/her choice on the picture sheets. Animal stickers were given to children as a reward at the end of the game and used as an incentive for the risk group.

*Procedure.* The child was shown the rubber stamp and told that s/he would need to use the stamp in the game. S/he was allowed to use it to make a stamp on a piece of paper.

The first trial was a warm-up trial. The child was given a picture sheet with four snowmen on it, identical but for different coloured noses. The child was asked to name the colour of the snowmen's hats (all pink) and their noses (different colours). S/he was then shown a picture card, with all the doors closed and told that there was one of the pictures from the sheet on this card and his/her job was to work out which one it was. The experimenter explained that she (the experimenter) would lift up the doors one by one to reveal the picture and that as soon as the child knew which one it was, s/he should stamp on the picture sheet.

Children in the risk group were told that if their choice matched the picture card then they would keep the card, if not the experimenter would keep it. If they won more cards than the experimenter did then they would win a sticker. The experimenter explained that, "you need to make sure you know which one it is before you stamp your sheet." Children were reminded of this before the experimental trials.

Children in the speed group were told that after they had made a choice, the experimenter would reveal the picture and then put the card and sheet away. They were also told that they would be given a sticker at the end of the game (with no mention made of their performance). Children were informed that the aim was to play the game as quickly as possible, and "as soon as you know which one it is you stamp your sheet". They were reminded of the need to play the game quickly before the experimental trials.

The experimenter lifted the doors slowly to reveal the snowman picture. On this warm-up trial she talked the child through the procedure. She explained that the child did not know which picture was hidden after the first door (which revealed only an uninformative



and uninteresting section of the picture). After the second door, which revealed the uninformative hat, she pointed out that now the child knew it had a pink hat, but that as all the snowmen did, the child still did not know which one it was. On the fourth door, the experimenter revealed the key feature, the nose and, if the child did not move to stamp the sheet spontaneously, she prompted him/her to do so.

The procedure was similar for experimental trials, except the experimenter did not prompt the child. The key feature was revealed behind the first, third or fifth door opened and each child had three trials, the information being revealed at a different point in each (these are referred to as 1trials, 3trials and 5trials). The order of presentation of the trials was counterbalanced between children. Four fixed orders were used to present the pictures on experimental trials (cup-bus-lady, bus-cup-lady, lady-bus-cup and cup-lady-bus). On the 3trials the narrowing section of the picture was always revealed by one of the doors before the disambiguating feature. This was inevitably true of 5trials. The point at which the child made an interpretation (using the stamp to mark the sheet) was recorded as the number of the door that had just been opened (i.e. 1 to 5).

At the end of the game, children in the risk group were encouraged to count how many cards they had and were given a sticker for winning (no child won fewer cards than the experimenter), children in the speed group were given a sticker as a reward for playing the game.

### **2.3 Results and Discussion**

Table 8 shows the data, scored as on which door children stamped for each trial. The shaded cells indicate the correct doors on which to stamp, that which revealed the disambiguating part of the picture.

**Table 8: Responses in stop game by trial on Experiment 6**

		Door on which child responded				
		1	2	3	4	5
Risk group n=22	1trial	7	2	2	2	9
	3trial	0	1	7	6	8
	5trial	0	0	2	0	20
Speed group n=20	1trial	10	3	2	1	4
	3trial	1	2	13	1	3
	5trial	0	2	0	1	17

Very few children made an interpretation too early, and no child made an interpretation too early on more than one trial. This supports my earlier claim that children are not unable to resist making an interpretation based on inadequate ambiguous information.

I tested whether children were discriminating between the trials. I ran a series of Chi Square tests, which compared the frequency of stamping on the correct door on each trial with stamping on that door on each of the other two trials. For example, I compared the number of children who stamped on the first door on 1 trials with those who stamped on the first door on 3 trials and in a separate test with those who stamped on the first door on 5 trials. I repeated this for 3 trials and 5 trials, see Table 9. Where the expected values were too small to run Chi Square tests I used Fisher's Exact test.

**Table 9: Chi Square and Fisher's Exact tests to compare performance between trials in Experiment 6**

	Door	Chi Square and Fisher's Exact test results (All tests are Chi Square unless noted)		
		1trial	3trial	5trial
Risk group	First door (compare 1trial to 3trial and to 5trial)	-	p(N=22)=0.008* (Fisher's)	p(N=22)=0.008* (Fisher's)
	Third door	p(N=22)=0.132 (Fisher's)	-	p(N=22)=0.132 (Fisher's)
	Fifth door	$\chi^2(df=1)=12.24$ , $p<0.001^*$	$\chi^2(df=1)=14.14$ , $p<0.001^*$	-
Speed group	First door (compare 1trial to 3trial and to 5trial)	-	$\chi^2(df=1)=10.16$ , $p=0.001^*$	$\chi^2(df=1)=13.33$ , $p<0.001^*$
	Third door	$\chi^2(df=1)=12.91$ , $p<0.001^*$	-	$\chi^2(df=1)=19.26$ , $p<0.001^*$
	Fifth door	$\chi^2(df=1)=16.94$ , $p<0.001^*$	$\chi^2(df=1)=19.60$ , $p<0.001^*$	-

\* indicates significance at 0.05.

For the speed group these comparisons show excellent discrimination between trials. However, for the risk group the results are less clear. Stamping on the correct door was more likely on the 1trials and 5trials but not on the 3trials. As children seemed to show a tendency to wait until the whole picture had been revealed (stamping on the 5<sup>th</sup> door), which is discussed in more detail below, we should be cautious in our interpretation of success on the 5trials. Although there is a trend towards stamping on the correct door by the risk group, the statistical tests show that discrimination in this condition was not good.

I also wanted to know if children were performing above chance on this task. I reasoned that if you stamp randomly at any point during the game, you have a 1/5 chance of

being correct on any one trial, as there are 5 doors after which you can make an interpretation. A probability tree illustrating chance performance is included in Appendix A. I used binomial tests to compare the frequency of stamping on the right door ( $p=1/5$ ) or any other door ( $p=4/5$ ) for each trial. For the risk group this test was significant only for the 5 trials: 1 trial  $p(N=22, y=7)=0.0768$ , 3 trial  $p(N=22, y=7)=0.0768$ , 5 trial  $p(N=22, y=20)<0.001$ . As already mentioned, children could stamp on the correct door on the 5 trial by waiting until the whole picture was revealed. Given this and the fact that children were no more likely than expected by chance to stamp on the correct door on 1 trials and 3 trials, the risk group's performance was not better than chance, when I considered individual trials. However, when I made the same comparisons for the speed group they performed consistently above chance: 1 trial  $p(N=20, y=10)=0.002$ , 3 trial  $p(N=20, y=13)<0.001$ , 5 trial  $p(N=20, y=17)<0.001$ .

I also considered the children's overall performance, that is on all three trials. As the probability of answering correctly on all three trials by chance is tiny, only 0.008 (1/125), I would need a sample of 125 children to expect even one child to chance upon the correct combination of doors. In the risk group ( $n=22$ ) 4 children did so and in the speed group ( $n=20$ ) 5 children did. Using binomial tests there were significantly more children who performed perfectly than would be expected by chance: risk group  $p(N=22, y=4)<0.001$ , speed group  $p(N=20, y=5)<0.001$ . Allowing children to make one or no mistakes, the probability of chance success is 0.104 (13/125). In my sample there were 9 children in the risk group and 15 in the speed group who met this measure of success. Once again this was significantly higher than expected by chance: risk group  $p(N=22, y=9)<0.001$ , speed group  $p(N=20, y=15)<0.001$ .

In summary, children in the speed group are both discriminating between the trials and performing well above chance. The performance of the risk group is less clear. Although the number of children making one or no mistakes or performing perfectly was above chance, when I considered individual trials or discrimination between the trials their performance was poor.

To see if the two groups differed in their performance, I compared the number of children who got two or more trials right (as the numbers were too small to test if I considered only perfect performance). Using this measure, there were 9 children in the risk group who succeeded and 13 who failed, and there were 15 children in the speed group who succeeded and 5 who failed. A Chi Square test showed that children in the speed group were more successful,  $\chi^2(df=1)=4.97, p=.026$ .

I also wanted to know if the risk group were more likely to be cautious than the speed group. Seven children in the risk group and three in the speed group consistently waited until the whole picture was revealed, which suggests a trend towards their being more cautious, although this was not significant using a Fisher's Exact test. I further investigated whether the risk group's performance was more cautious than the speed group's by comparing the number of children in each group who stamped on a door after the disambiguating part had been revealed on every trial (but did not necessarily wait until the very end). There were significantly more in the risk group (11 children who were consistently late and 11 who were not) than in the speed group (3 children who were late and 17 who were not),  $\chi^2(df=1)=5.78, p=.016$ . From this I concluded that although there is no difference in the number of children who succeed (absolutely) on the task between the risk and speed groups, nor in the number of children who consistently wait until all the doors are opened to make a response, there is a tendency for the speed group to be more accurate overall and for the risk group to delay.

This finding is interesting because I had expected that children would tend to make interpretations too early when they were in the speed group and that perhaps, increasing the risk would cause them to pay more attention to the problem and could reveal good performance. However, as can be seen from Table 8, very few responses were made before the disambiguating information was seen (3 (4.5% of all responses) by the risk group and 6 (10%) by the speed group). The risk group, who were generally late, were being more cautious in their interpretations, and this meant that in one sense, their performance was worse than the speed group, as they were less likely to stamp correctly on two or more trials.

Of course, the strategy the risk group are using, waiting for redundant information, is a reasonable one and one which adults might use in high risk situations. If there is no advantage in making an immediate interpretation, then an adult might wait for extra information. It is wrong to think of them waiting for more confirming evidence – after all the information they have is sufficient, but it is understandable when there is nothing to be lost. If a person understood about what information is sufficient to make an interpretation and the limitations of partial information, then s/he would know that the extra information gained after the disambiguating item is superfluous. It is an open question from these results whether the children in the risk group are aware of this, but given the good performance by the speed group we might think it likely that they do know when they could have made an interpretation. Interestingly, there were relatively few children in either group who waited for the whole picture to be revealed (although there were more in the risk group), which is a very cautious strategy. However, there was a tendency especially in the risk group not to make an interpretation immediately on having sufficient information.

A second important finding from this experiment is the overall good performance by young children in resisting making an interpretation while they only have ambiguous

information on which to base it. No child was consistently early (answering on the correct door on the 1trial and before the disambiguating information on the 3trial and 5trial) and very few interpretations were made based on ambiguous information.

There are two possible interpretations of this finding:

- 1) Children do recognise information that is sufficient to make an accurate interpretation. In this procedure, I attempted to remove the demands of planning what to do when you encounter different types of information by not requiring that the child actively choose a strategy to deal with ambiguity. After each door is opened, one can either make an interpretation or wait for the next door, but unlike my earlier strategy selection experiments, this is not a choice that the child is explicitly asked to make. The default is to wait and the child has actively to choose when to make an interpretation. Certainly success on this task does not reveal a broad competence in responding to ambiguity. Specifically, it does not show any understanding of what can be done to remove the uncertainty one feels. But when the emphasis of the task is moved to only identifying when you do know, children's performance seems good.
- 2) The children I tested in this sample were very near the end of the school year, and although I would have expected them to fail standard ambiguity tasks, I have no comparison with such a task. I did not expect such good performance by the speed group – as the literature suggests children are keen to interpret ambiguous messages. My alternative behavioural tasks have shown that this is not always the case, but those results would not lead to the prediction that children in the speed group would do so well on this task – making the interpretation at the correct point, rather than at a random point. Given this, I had expected to make a comparison between a speed group over keen to make an interpretation and a risk group who might be encouraged to delay past

the ambiguous information (because they were generally more cautious), but who might then have been able to identify when they knew. So the speed group's good performance is unexpected and might be the result of the fledgling abilities suggested in 1 above. However, it is possible that the success of the speed group would have been matched by good performance on other ambiguity tasks. From these data alone, I cannot claim that children who have difficulty choosing between different strategies and evaluating ambiguous information, nevertheless are able to delay an interpretation and make it only when they really know, if the information is presented in such a way that they do not have to choose explicitly whether or not to make an interpretation.

To resolve this I ran a second experiment using the stopping procedure and compared it to the cones game, which young children have found difficult (Experiments 3 and 5). I used only the speed procedure as children had been so successful on this version of the task.

### 3 Experiment 7: Is the stop game easier than the cones game?

#### 3.1 Method

*Participants.* I tested 42 children from an infant school, serving a middle class population in Birmingham, UK. Data from one child were excluded, as he had difficulty naming colours, leaving 24 girls and 17 boys, with a mean age of 5 years and 6 months (5;6), range 5;1 – 6;0.

*Materials.* I used plastic cups, a plastic doll with a set of toys and a mat as in Experiment 5 for the cones game. For the stop game, I used the same materials as for Experiment 6: four picture cards, with doors cut so that parts of the picture could be revealed, picture sheets with sets of four pictures on them and a rubber stamp and stamp pad.



*Procedure.* Each child participated in two games. The order of presentation of the two games was counterbalanced between children. The procedure for the cones game was the same as that used in Experiment 5 and for the stop game was the same as the speed procedure in Experiment 6. I counterbalanced the order of trials in the stop game and in the cones game (there are six possible orders of presentation in the stop game and two possible orders in the cones game (ambiguous first or informative first) so there are twelve possible orders in total). I used three different orders to present the pictures to the children (cup-lady-bus, lady-bus-cup, bus-cup-lady). This procedure differed from the stop game in Experiment 6 in that the presentation of the piece of narrowing information was systematic; it was always revealed by the second door on the 3 trials and by the third on the 5 trials.

### **3.2 Results and Discussion**

*Cones Game.* I ran a repeated-measures ANOVA to compare performance on ambiguous and informative trials and to identify any order effects on the cones performance. Trial type (ambiguous or informative) was included as a within-subject factor and game order (cones or stop first) and cone order (ambiguous or informative first) were included as between-subject factors. Unlike my results from Experiment 3, children discriminated between ambiguous and informative trials,  $F(df=1,37)=6.554, p=.015$ . They were more likely to pick up the cones in response to the former (mean score on ambiguous trials 1.22, mean score on informative trials 0.88). There were no interactions between trial type and the order factors and there was no main effect of either order. However, there was an interaction between game order and cones order,  $F(df=1,37)=4.963, p=.032$ , mean scores are given in Table 10. If the cones game is played first, children tended towards the strategy of the first trial (ambiguous or informative). As this did not interact with trial type there was no effect on children's overall performance on the cones game and I checked that the number of children

**Table 10: Mean scores on cones game by cone order and game order**

		game order	
		stop first	cones first
cones order	ambiguous first	0.955	1.444
	informative first	1.167	0.625

Despite the discrimination between ambiguous and informative trials, children’s performance on the cones game was poor. The mean scores (1.22 on ambiguous trials and 0.88 on informative) are close to chance, which is to score 1 out of 2 on each pair of trials, and the number of children using the correct strategy is low. Only 15 children (36.6%) were successful, even allowing for one deviation from the correct strategy (the adjusted strategy), which is comparable to the 8 children (31%) doing this in Experiment 3. Without making any allowance for errors only 3 children (7.3%) used the correct strategy throughout (in Experiment 3, 4 (15%) children did so).

I compared the number of children performing correctly on the cones game with that expected by chance (1/16 for absolute, 5/16 for adjusted). As we would only expect 3 children in a sample of 41 to perform absolutely correctly by chance, I used a Chi Square test to compare the expected frequency of children using an adjusted strategy by chance, 12.8,

with the observed frequency, 15. As is clear from the figures, there was no difference between the observed and chance performance,  $\chi^2(df=1)=0.55, p=.46$ .

*Stop Game.* I recorded on which door the child stamped the picture sheet. Data are shown in Table 11:

**Table 11: Responses in stop game by trial on Experiment 7**

	door on which child responded				
	1	2	3	4	5
1trial	17	5	5	3	11
3trial	0	5	15	5	16
5trial	0	0	8	0	33

The shaded cells indicate the correct doors on which to stamp, the one which revealed the disambiguating part of the picture. My first question, as with the cones game, was to identify whether children were discriminating the trials from each other. As in Experiment 6, I ran a series of Chi Squared tests, which compared the frequency of stamping on the correct door on each trial with stamping on that door on the other two trials, see Table 12.

**Table 12: Chi Square test results comparing discrimination between trials**

Door	Chi Square results		
	1trial	3trial	5trial
First door (compare 1trial to 3trial and 5 trial)	-	$\chi^2(df=1)=21.44,$ $p<0.001$ *	$\chi^2(df=1)=21.44,$ $p<0.001$ *
Third door	$\chi^2(df=1)=6.62,$ $p=0.010$ *	-	$\chi^2(df=1)=2.2$ $p=0.085$
Fifth door	$\chi^2(df=1)=23.74,$ $p<0.001$ *	$\chi^2(df=1)=14.66,$ $p<0.001$ *	-

\* indicates significance at 0.05.

All Chi Square tests were significant except for the frequency of stamping on the third door on 3 trials and 5 trials. Remember that on the 5 trials, the narrowing (helpful but not disambiguating) part of the picture was revealed by the third door. Some children were clearly making a mistake here, acting as if the narrowing information was sufficient for them to make an interpretation. I accepted the overall tendency to discriminate between the trials, but return to children's misinterpretation of narrowing information below and explore this in Chapter 5. Finding that children discriminated between the trials, suggested that it is worth continuing the analysis to explore whether children can be described as successful on this task. As I have shown with the cones task, merely discriminating between trials as a group does not necessarily mean that children perform very well on a task.

As with the cones game, I compared children's performance with that expected by chance. There is a 1/5 chance of being correct on any one trial (as in Experiment 6). The sample in this experiment is larger than that in each of the groups in Experiment 6, and the expected number of children who would stamp by chance on each cell is 8.2, so I could use Chi Square tests to compare the number of children responding correctly or incorrectly on each trial against chance. These were all significant: 1 trials  $\chi^2(df=1)=11.80, p=.001$ ; 3 trials  $\chi^2(df=1)=9.88, p=.002$ ; 5 trials  $\chi^2(df=1)=93.76, p<.001$ . I also considered the children's overall performance on all three trials. As in Experiment 6, there was a tiny probability of responding correctly on all three trials by chance and I would need a sample four times the size of that used in this experiment to expect even one child to chance upon the correct combination of doors.. In this sample 8 children stamped on all three correct doors. This was significantly different from chance using a binomial test  $p(N=41, y=8)<0.001$ . There was also a significant difference between the number of children making 1 or no mistakes and the number expected by chance  $p(N=41, y=13)<0.001$ .

I also compared the number of children getting 2 or more trials correct in this sample with the children in Experiment 6, to see if they were performing as well as my earlier sample. As for my comparison between Experiments 5 and 3, my conclusions drawn from this are cautious due to the separate samples. In Experiment 6, 15 of the 20 children in the speed group (the same procedure used for all children in this experiment) answered 2 or more trials correctly. This is significantly different using a Chi Square test,  $\chi^2(df=1)=10.15$ ,  $p=.001$ . As I suspected, it appears that the children in Experiment 6 performed very well. Despite the difference in performance between the samples in Experiments 6 and 7, performance on the stop game by the current sample of children was better than chance and discriminating. I move now to the most important comparison, the motivation for running this experiment: did children find the stop game easier than the cones game?

*Comparison between stop and cones games.* A straightforward comparison between absolute performance on the two games is inappropriate because of their different baselines. As I have explained already, the probability of responding correctly by chance on all 4 cones trials is 1/16, but the probability of responding correctly by chance on the three stop trials (because there are five doors on each trial) is only 1/125. I considered the probabilities of making various patterns of responses in each game, to find an appropriate and fair comparison, see Table 13.

In Table 13 the probability of each measure of success happening by chance is given as a decimal along the row or column headings. These are calculated from the probability trees in Appendix A. I needed to find two measures of success on the games, which were close in probability. I divided the probability of success on the cones game, by that on the stop. This allows us to judge how comparable the two measures of success are. For example, as the probability of making one mistake on the cones task is 0.3125 and on the stop is 0.104,

we can describe success on this measure of the cones game as 3.005 times (0.3125/0.104) more likely than on the stop game.

**Table 13: Comparison of probabilities for measures of success in stop and cones game**

		Cones		
		Perfect performance ( $p=0.0625$ )	1 (or fewer) mistakes ( $p=0.3125$ )	2 (or fewer) mistakes ( $p=0.6875$ )
Stop	perfect performance ( $p=0.008$ )	7.8125	39.0625	85.9375
	1 (or fewer) mistakes ( $p=0.104$ )	0.6010	3.0048	6.6106
	2 (or fewer) mistakes ( $p=0.488$ )	0.1281	0.6404	1.4088
	correct on any two specified trials ( $p=0.04$ )	1.5625	7.8125	17.1875
	correct on any one specified trial ( $p=0.2$ )	0.3125	1.5625	3.4375

The closer the figure is to 1 the better the comparison. Furthermore, given the apparently good performance on the stop game (it was better than chance, unlike the cones game), I sought a comparison where the probability of success on cones was greater than that on stop, so that my test of whether the stop game was easier than the cones game was strict. Comparisons which meet this criterion produce decimals greater than 1.

Three comparisons (shaded cells in the table) approach equivalence (nearing 1) and meet the requirement that the probability of being judged successful on the stop game is less than that for the cones game:

- 1) comparing between making 2 or fewer mistakes on each game (0.6875 (cones) /0.488 (stop) =1.409)

- 2) comparing perfect performance on cones against correct performance on two predetermined stop trials ( $0.0625$  (cones) /  $0.04$  (stop) =  $1.563$ )
- 3) comparing adjusted performance on cones (making 1 or no mistakes) with performance on any one specific trial on stop ( $0.3125$  (cones) /  $0.2$  (stop) =  $1.563$ )

The first comparison is unsuitable. Firstly, the threshold for 'success' on each task is now very low (performing correctly on only half of the cones task and only a third (just one) of the stop trials). Secondly, the probabilities are such that on the cones task you are now more likely that not to be included as correct if you were performing randomly, and you have an almost 50/50 chance of 'correct' performance on stop. Importantly, children who consistently wait until the whole picture is revealed on the stop game, or use a consistent looking or moving strategy on the cones game are now scored as correct. Finally, only 7 of the 41 children are now categorised as making any mistakes.

I used 2-tailed binomial tests to make the second comparison. Performance on stop 1 trials and 3 trials (together) was significantly different to perfect performance on cones (1 child performed correctly on cones but not on stop 1 and 3; 10 showed the reverse pattern,  $N=11$ ,  $k=1$ ,  $p=.012$ ). Similarly, performance on stop 1 trials and 5 trials was better than the perfect cones measure (1 child passed cones but not stop 1 and 5; 9 showed reverse pattern,  $N=10$ ,  $k=1$ ,  $p=.04$ ) and this was also true for stop 3 trials and 5 trials (1 child passed cones but not stop 3 and 5; 9 showed the reverse pattern,  $N=10$ ,  $k=1$ ,  $p=.04$ ).

I also ran binomial tests to make the third comparison. However, the comparisons between 1 trials and adjusted cones, and 3 trials and cones were not significant ( $N=16$ ,  $k=7$ ,  $p=.804$ ;  $N=16$ ,  $k=8$ ,  $p>.999$ , respectively), although the comparison was significant for 5 trials,  $N=22$ ,  $k=2$ ,  $p<.001$ .

In drawing a conclusion from this somewhat inelegant analysis, I considered several results:

Firstly, performance on the cones game was no different from that which would be expected if children were selecting randomly between the two strategies available. This is true whether I considered perfect performance or use the more lenient adjusted test, allowing children to make one mistake from the perfect pattern. This is in keeping with findings from Experiments 3 and 5. In contrast, performance on the stop game is consistently above chance. Again, this is true of absolute scores or allowing children to make a mistake, and also if I considered each trial individually.

Making comparisons between the two tasks is difficult because of the unequal baselines. The closest comparison available requires us to use a measure of success on each game that is so weak that it would be unwise to claim that it revealed good performance on a task (the first possible comparison above). By considering only certain trials on the stop game, there is a difference between success on the stop game and cones if the requirement is perfect performance on two, specified, trials (second comparison), but there is no difference between stop and cones if only one trial is compared to adjusted performance. Although the second and third comparisons are in conflict, I argue that the former tells us more about the children's performance on the stop game overall as the child must pass two trials, rather than just one. Children's good performance, indicated by their better than chance performance overall, is seen in their ability to perform well on all trials. Considering only one reduces the impact of this performance.

It seems that children's performance was better on the stop game than the cones game. I remain cautious in claiming this and in Chapter 6, Section 2.1, Future Research, I suggest directions which would allow me to refine this comparison.



I acknowledge that even if children's performance on the stop task was better than that on cones, it was certainly far from perfect. Their performance was not as good as the slightly older children in Experiment 6. Furthermore, two types of error occur most obviously which need to be noted: The first was stamping when a narrowing but not disambiguating piece of information was revealed and the second was always waiting until the whole picture was revealed.

1) Interpreting when a narrowing piece of information is revealed: From Table 11 we see that if children ever stamped before the disambiguating piece of information was revealed this was always on the door which revealed the narrowing part. The frequency of doing this was relatively low and despite this, children's performance on the stop game was still quite good. However, these errors lead me to claim:

Firstly, that children's performance on this task was good when the information they saw told them nothing new about the picture (it is uninformative). They never stamped when a completely uninformative part of the picture was revealed (before the disambiguating part). They might have stamped on the narrowing part, because they confused any information which told them something, or allowed them to reject certain options, with that which fully disambiguated their choice. Alternatively, they might have made a comprehension monitoring error, where because they now knew something, they mistakenly thought they could be sure. It is not inconceivable that an adult might under certain circumstances make this error for the second reason. In Experiment 1, I found no difference in evaluations of knowledge based on uninformative and narrowing messages. The response is very different in this task. Rather than evaluating an isolated state of knowledge in terms of certainty (as in the pictures task), in the stop task one is 'looking out' for a feeling of certainty. If children mistake a change from knowing nothing to knowing something as one which allows you to

interpret the information, this may cause children extra difficulties with ambiguous input. I explore possible confusion about narrowing and uninformative information in the next chapter.

Secondly, a concern with this procedure is that children might not be able to act quickly enough to stamp on their chosen door and so might appear to be late, when in fact they had identified the disambiguating information on the correct door. The only reason to have stamped on door 2 on 3 trials or 3 on 5 trials preferentially is that the information revealed was different from that on door(s) 1 on 3 trials or 1, 2 or 4 on 5 trials. Thus, these errors suggest children were able to respond quickly enough to specific doors.

2) Waiting for the whole picture to be revealed: there was a subgroup of 10 children who consistently waited until the whole picture was revealed before stamping. Using this procedure I am unable to distinguish between children using a very cautious, but sensible strategy of waiting for maximum information, which was acceptable as there was no disincentive to do this, and children who were baffled by the task and waited until they were obliged to make an interpretation when the whole picture was revealed. I considered removing this subgroup from my analysis and analysing the group's performance without them. However, this is out of keeping with my previous strategy in analysing the cones game – where children might have used a consistently cautious or overconfident strategy, but I judged competence in terms of discriminating between the trials. I claimed that this was a fair test, as children saw the different strategies in the warm-up trials at the outset and because of the tendency in the older group in Experiment 3 to use an appropriate mix of strategies. (The tendency to be overcautious in the older group (in Experiment 3) was very low, only 3 of 30 children in this group consistently picked up a cone.) My inclusion of the children who consistently waited in the stop game is itself cautious. These children only respond correctly

on one trial and so are not counted as successful in any of my comparisons with the cones game (except when I compared only the responses on 5 trials with adjusted cones scores). For my conclusions, these children alert us to the possibility of children being cautious but competent in handling ambiguity. Exploring children's ability to reckon with a disincentive is beyond the scope of this thesis, but I propose future research which would investigate this in Chapter 6, Section 2.1.

#### 4 Discussion of Experiments 6 and 7 and Summary

In these two experiments I sought to explore a specific skill, monitoring certainty, which I claimed was necessary before children can effectively plan appropriate strategies to handle ambiguity. Although I found good performance on the speed version of the stop game in Experiment 6, a second experiment, Experiment 7, was needed to test whether children found this task easier than the cones game, which does involve strategy selection, or planning. Performance on the stop game in the second experiment seemed less good than that in Experiment 6, but overall I concluded that children did find this task easier than the cones game. Importantly, children's tendency was not to stamp too early, before the piece of disambiguating information was revealed (only 11% of responses in Experiment 7 were of this type). My aim was to see if a problem with monitoring certainty and uncertainty could be the reason for children's difficulties with ambiguity tasks. If certainty monitoring was a problem for young children, they could misinterpret an input which should leave them uncertain as one which allowed them to be certain. This would lead them to make interpretations too early in the stop game.

The results from the stop game do not support this. Children were overcautious rather than overconfident, and on a large number of trials stamped after the disambiguating piece of information had been revealed. This suggests that they may have a problem responding

confidently when they do know. Whether this is due to a legitimate reasoning by the child that s/he may as well wait for redundant information, or an inability to pinpoint the change from uncertainty to certainty, cannot be known from these data, and I consider further work which would address this in the General Discussion, Section 2.1. Other errors suggest that sometimes children had problems distinguishing absolute certainty from just knowing more (those who stamped on the narrowing window). It is likely that children have some difficulties monitoring certainty, but the limited skills they have revealed through the stop game suggest that their (un)certainty monitoring is adequate for them to select strategies on an ambiguity task.

Previous research suggested that children's tendency when confronted by ambiguous input was to overinterpret it and, as discussed in the Introduction, this response might be the result of a misunderstanding about ambiguity (the child genuinely thinks that the input is good enough to justify interpretation) or an informed strategy, such as making a guess (as suggested by Speer, 1984). Results earlier in this thesis have questioned the second of these possibilities, children have difficulty seeking information even when it would improve the quality of an interpretation and is directly related to their goal, and they do not simply tend to make interpretations of ambiguous input (see the errors made in Experiment 3). In this new procedure, the stop game, I removed the need to decide what to do with ambiguous input, but instead explored a subcomponent skill – that of monitoring (un)certainty. Children's performance on the stop game was relatively good compared to the cones game, yet certainly not perfect. However, their tendency to be overcautious rather than overconfident suggests that a problem monitoring uncertainty cannot be the whole story behind children's problems with ambiguity tasks.

My use of “certainty monitoring” here does not address whether the child is aware of their uncertainty or certainty, or whether they actively decide to respond based on this (un)certainty. There is further work which could investigate more fully children’s awareness of and sensitivity to any feelings of uncertainty. Recently a betting task (Ruffman, Garnham, Import and Connolly, 2001) and rating scales (Ruffman, Rustin, Garnham and Parkin, 2001) have been used to probe children’s appreciation of their uncertainty. I noted in my introduction that in this thesis I would avoid evaluative measures of uncertainty, of which a rating scale is one example, however, they may prove useful in development of tasks like the stop game, out of the context of responding to ambiguous input. These types of procedures would provide interesting information about children’s understanding and awareness of uncertainty and certainty. However, for my purposes, knowing that children are able to respond based on (un)certainty in a game like the stop game is sufficient. As I explained above, for children to fail ambiguity tasks due to a problem monitoring uncertainty they would need to fail to discriminate information which should leave you uncertain from that which allows you to feel certain. Children’s ability to withhold responding in this tasks until after the disambiguating part of the picture has been revealed, suggests that we cannot explain young children’s difficulty with ambiguity as one of recognising whether ambiguous information allows you to feel certain or not. In Chapter 5, I address the second of the skills identified in the introduction to this chapter: that of knowing what would disambiguate ambiguous input.

In Experiment 6, I also used an element of risk, in an attempt to improve performance by dissuading children from making an interpretation too early. Rather than improving performance, these children’s performance was worse than that of the speed group, who were encouraged to interpret as soon as they knew, on my measure of success. The behaviour of

the risk group was reasonable within the context of the procedure, as there was no disincentive for waiting for redundant information. This experiment is especially useful in that it highlights that increased risk might not always simply improve the performance of young children, but might encourage them to use an alternative approach altogether, in this case being overcautious. In the General Discussion, Chapter 6, I discuss the use of a disincentive to encourage children to reveal their understanding of when they do know something as soon as they can.

## Chapter 5 Identifying Disambiguating Information

### 1 Introduction

In Chapter 4, I concluded that difficulty monitoring certainty could not be the whole story behind children's difficulty with ambiguity tasks. Although performance was not perfect on the stopping task, which required a response only when the child knew which referent was intended, performance was generally good and above chance. Children tended to respond at the specific point when they could disambiguate a message. In this chapter I turn to the other skill that I proposed should facilitate handling of ambiguous input: that of knowing what one needs to find out. I will use the results from Experiment 8 to suggest why children, who are reasonably competent at monitoring their certainty, might find the cones task difficult.

I made the test of knowing what you need to know as simple as possible for the child. I wanted to find out whether children knew that a problem arises because there are two items which share certain key attributes. For example, in my early pictures task both the rabbit and the cow pictures could be described by the clue "It's black and white". I used a similar type of procedure to the Pictures and Stopping games, in which children had an array of pictures and had to identify the experimenter's target. In keeping with my decision to avoid the need for explicit strategy planning on the part of the child, and as in Experiments 1 and 2, where children had performed so well, the experimenter scaffolded the process of identifying the target for the child.

In previous research children had been asked to identify disambiguating information. In Lloyd's task, children had to ask questions to disambiguate a message, but they performed poorly on this task and did not ask questions which pinpointed the key disambiguating

information (Lloyd et al, 1995). Although this might support the suggestion that children have difficulty identifying what they need to know, the task also involves strategy selection: children heard both ambiguous and unambiguous messages and could choose a referent immediately without asking for any extra information. Furthermore, posing a question to target the specific information you need to find out (rather than a general question “What’s it like?”) might cause the children difficulty. In Experiment 8 I avoid both these criticisms, by offering children a forced choice between two pictures. There is no need to formulate a question, nor (I think most importantly) does the child have to decide whether to seek extra information or to make an interpretation. My assessment was of whether the children can discriminate disambiguating information from that which leaves the information ambiguous.

It is important here to clarify what I mean by discriminate. I am not suggesting that children physically cannot tell the difference between the two objects (even though it might be that in some cases two possible referents might look identical, they are logically distinguishable at some level, for example by pointing to one and saying “This one?”). Indeed I have already asked children to identify key features of potential referents of ambiguous messages (see for example Experiment 2). Rather I sought to test whether they realise what information would allow them to make discriminations between the items. If children are unable to do this, then many strategy selection tasks are asking children to seek extra information which they are unable to identify.

## 2 Experiment 8 Useless clues

### 2.1 Introduction

Children played a game in which they had to identify a target picture on a card from a set of five. They were not allowed to make an explicit interpretation on hearing the



ambiguous message, but instead were obliged to choose between two pieces of information, one that would disambiguate an ambiguous message and one that would not. For example, on one sheet there were four buses and one lorry. The buses were identical, apart from each had a different coloured door. Having heard a first clue that the target picture was a bus, the child was given the choice of finding out about the colour of the door, which would disambiguate their choice, or the wheels (all the same colour), which would not. I reasoned that if children understood how to discriminate the potential referents then they would select the disambiguating clue, in this case the door. I recognised that not allowing children to make a verbal interpretation does not stop them from making a private one, but I have already shown in Chapter 3 that children do not fail ambiguity tasks just because they are unable to resist making an interpretation.

My hope was that having removed the demands of choosing a strategy and also of understanding its consequences – i.e. why you need to ask for more information – children would at least reveal an ability to select the information that would help them. Importantly, merely being able to identify disambiguating information is not a sign of understanding ambiguity nor would good performance on this task mean that children were employing an appropriate strategy to deal with ambiguity. At its most basic, this understanding might only be that the child can identify the potential referents and recognises that they differ on one feature but not on another. The child would not necessarily understand that the message itself was inadequate, nor that if one wanted to make an accurate interpretation it would be appropriate to seek more information. Rather this is a diagnostic experiment in which I explore a component of the process of disambiguating, out of context.

When given the choice between a useful, disambiguating clue and a useless clue (which gave them no information to narrow their choice), children might select the useful

clue. Then we might assume that they have some understanding of what is wrong with the message – they at least know what would be of use for them to make a more accurate interpretation. However, it might be that children can select between the useful and useless clue without understanding that the useful clue will help them to narrow the referents of the message. They might use an alternative rule of thumb when trying to choose between the useful and useless clues. Looking at the pictures of the four buses, you know the information available from the useless clue, the wheels, because all the pictures share it (at least all the items which fit the first clue), so you can treat it as uninteresting from the start. In this case to learn anything new you should ask for the other (disambiguating) clue the doors. To investigate this possibility, a second set of trials compared useful with narrowing clues, which referred to the feature that is of one type for half the potential referents and another type for the other half (e.g. on a different picture sheet two of the four buses had orange wheels and two had blue). This feature did not tell you enough to disambiguate the message and make an accurate interpretation. If children dismiss the useless clue because they know it could tell them nothing but do not understand that they need to disambiguate the message, then they may choose the narrowing clue which will provide some, but limited, information. Remember that in the stop game, we saw that when children made interpretations too early, they were nearly always when the narrowing part of the picture was revealed, rather than an uninformative part. Experiment 8 explored whether children are confused about the relative value of disambiguating and narrowing information. Because of the possibility that children could pass the useless trials using a “rule of thumb”, the narrowing trials were a more strict test of whether the child can identify disambiguating information.

## **2.2 Method**

*Participants.* I tested 46 children from two infant schools, serving predominantly working and middle class populations in Birmingham, UK. Data from two children were excluded due to experimenter error, leaving 17 boys and 27 girls, with a mean age of 5 years and 10 months (5;10), range 5;2 – 6;10.

*Materials.* I used a small plastic doll, a set of toys and coloured plastic cups, as in Experiment 5, for the cones game. For the clues game I used picture sheets showing five pictures (e.g. four buses and one lorry). On useless clue sheets four of the pictures were identical but for one feature (e.g. doors), which was a different colour on each picture. There was a second feature on which the fifth picture was also the same as the other four (e.g. all four buses and the lorry had blue wheels). On the narrowing clue trials the pictures differed on one feature as in the useless clue trials, and a second feature divided the pictures into two groups: two of the potential referents in one group, and two potential referents and the extra picture in a second group (e.g. two buses had orange wheels and two buses and the lorry had blue wheels). The experimenter held an envelope that had several of the pictures in (although the child was told it contained only one) and I used two pieces of paper with line drawings on them of the two features (door and wheels) to give the child a forced choice between the two clues on each trial. I used four sets of picture sheets – in two useless clues were presented first, in two narrowing clues were presented first. The order of pictures and the features which were used for clues are shown in Table 14. Primary features were used for disambiguating clues, secondary features were used for narrowing or useless clues.

**Table 14: Picture sets for clues game**

trial type	Picture set A			Picture set C		
	pictures	primary	secondary	pictures	primary	secondary
useless	bus	wheels	door	cat	bow	eye
narrowing	snowman	hat	nose	boy	jumper	shoes
useless	lady	bag	hat	cup	flower	handle
useless	cat	eye	bow	bus	door	wheels
narrowing	boy	shoes	jumper	snowman	nose	hat
narrowing	cup	handle	flower	lady	hat	bag
	Picture set B			Picture set D		
	pictures	primary	secondary	pictures	primary	secondary
useless	snowman	hat	nose	boy	jumper	shoes
narrowing	bus	wheels	door	cat	bow	eye
narrowing	lady	bag	hat	cup	flower	handle
narrowing	cat	eye	bow	bus	door	wheels
useless	boy	shoes	jumper	snowman	nose	hat
useless	cup	handle	flower	lady	hat	bag

*Procedure.* All children played both the cones and the clues games. The order of the games was counterbalanced between children.

The procedure for the cones game was the same as that in Experiment 3. Each child had two warm-up trials: one ambiguous followed by an informative trial. Then there were two ambiguous and two informative experimental trials, which were alternated. Order of the first trial, ambiguous or informative, was counterbalanced. Unfortunately, I confounded the clues order (useful or narrowing clues first) with the game order: children who played the clues game first always had the narrowing trial first. Although it might be harder to be

confronted by the narrowing trials first, rather than the simpler useless trials, there were no order effects (see Section 2.3 of this chapter) and so it is unlikely that this affected children's performance.

In the clues game the child also had two warm-up trials and four experimental trials. In a trial the child was shown a set of pictures (as described in the materials section above) and asked to name them. Most of the children (but not the first 17 tested) were asked to name the colours of the primary and secondary features (e.g. name the colours of all the doors and wheels). This was included to ensure that children had attended to all the pictures and served as an extra check for colour blindness. On the warm-up trials the experimenter explained to the child that she had a picture of one of the items on the sheet in an envelope and the child's job was to identify it. She showed the child the corner of a picture out of the top of the envelope (showing only the paper, not the picture itself). The experimenter gave the child the first clue that narrowed the choice from all five pictures to only the four similar pictures (e.g. "It's a bus"). The experimenter explained that the child could then choose one of two clues. She placed a card showing a black and white line drawing of wheels and one of a door on the table and explained that the child could find out about the colour of the wheels or the door. In the warm-up trials the experimenter talked the child through the procedure: she explained that the child could find out what colour the wheels were, but that all the buses had the same colour wheels so "that's not much help". She explained that they all had different coloured doors so that was more helpful. The experimenter then told the child the colour of the door (the useful clue), the child chose the appropriate picture and was shown that this was the same as the one in the envelope. A second warm-up trial offered the child the choice between a useful clue and a narrowing clue. On this trial, the pictures differed on the secondary

feature but were not uniquely identified by it: finding out about the secondary feature would not disambiguate the first clue.

There followed four experimental trials. Two gave the child the choice between useful and useless clues (useless trials) and two gave him/her the choice between useful and narrowing clues (narrowing trials). These were presented in two pairs – both useless trials followed by both narrowing or vice versa.

If the child chose the useful clue, s/he was shown a matching picture from the envelope to indicate that s/he had got the right one. If s/he chose the useless or narrowing clue s/he could either be given good or bad feedback, i.e. s/he could either be shown a picture that matched his/her choice, or contradicted it. This feedback was unsystematically varied, but recorded.

### **2.3 Results and Discussion**

*Cones game.* To investigate performance on the cones game, I ran a repeated measures ANOVA with trial as a within-subject variable (ambiguous or informative) and order (cones or clues game first, and ambiguous or informative trials first in the cones game) between child. The ANOVA showed no main effects of order and no interactions with this factor. There was a main effect of trial type,  $F(df=1,40)=4.626, p=.038$ . Children were discriminating between ambiguous and informative trials. However, their performance was still not good: only 8 children (18%) used a correct strategy overall. If children responded at chance we would expect about 3 children (exactly 2.75 as  $n=44$ ) to use an overall correct strategy. Even when the children were given the benefit of the doubt and allowed to deviate from the correct strategy on one trial (the adjusted cones strategy) only 15 (34%) of children used a correct strategy (13.75 expected by chance). Considering only the completely correct strategy, there may be slightly more children than expected by chance, but the expected value

is too small to test using a Chi Square. There is no reason to think that children performed differently to chance when we turn to the adjusted strategy. This is in keeping with the cones performance in previous experiments (Experiments 3, 5 and 7).

*Clues game.* Performance on the clues game is shown in Table 15. Children scored 1 on each trial where they chose the useful rather than useless or narrowing clue. These are summed to give a score out of 2 for both useful/useless trials and useful/narrowing trials. I first ran t tests to check that there was no difference in performance between the children who were asked to name the colours of the features on each trial, and those who were not (the first 17 tested). For both narrowing and useless trials, the two groups' mean scores were not significantly different.

I ran a repeated measures ANOVA with trial as a within-subject variable (useless or narrowing) and included order as a between-subject variable (clues game and narrowing trial first or cones game and useless trial first, as explained in the Method, Section 2.2). As in the cones game, there was no main effect of order and no interaction with order. There was a main effect of trial,  $F(df=1,42)=4.264, p=.045$ , which showed that children's performance was better on useless trials (mean score 1.417) than on narrowing trials (mean score 1.204). Eleven children (25%) performed perfectly, choosing the useful clue throughout.

**Table 15: Comparison between performance on narrowing and useless trials**

		Narrowing		
		0	1	2
Useless	0	4	1	1
	1	2	10	2
	2	0	13	11

We can see from the ANOVA that children performed differently on useless and narrowing trials. To make a judgment about how good their performance is on these two types of trials, I compared each against chance performance (selecting randomly between the clues would give a distribution of 11 children scoring 0 (25%), 22 scoring 1 (50%) and 11 scoring 2 (25%)). Using Chi Square tests I found no difference in performance between a chance distribution and performance on the narrowing trials,  $\chi^2(df=2)=3.27, p=.195$ , but the useless trials differed significantly from chance,  $\chi^2(df=2)=20.55, p<.001$ . From the table we can conclude that children are performing above chance on the useless trials, tending to select the disambiguating rather than the useless clue.

*The effect of feedback.* Feedback was recorded for all children (except five from the beginning of the sample). Children who chose the useless or narrowing clues were given either ‘consistent’ or ‘contradictory’ feedback. The former meant they were shown the picture which matched their final choice, the latter that a different picture was shown. To assess the effect of feedback I considered the child’s performance on the trial immediately following that on which they had received feedback. These data are shown in Table 16. (n.b. as some trials on which feedback were given were the last in the game, these are not included in the table as there is no following trial). For simplicity I have combined feedback given on useless and narrowing trials.

**Table 16: Performance on trial immediately following feedback**

type of feedback	clue chosen on following trial (frequency for feedback on useless/narrowing trials in brackets)	
	useless/narrowing	useful
consistent	11 (6/5)	17 (3/14)
contradictory	5 (4/1)	4 (4/0)



As can be seen there was more consistent than contradictory feedback. Whether children had consistent or contradicting feedback had little effect on their response to the next trial (although there was a slight trend towards more correct answers following consistent feedback, in particular if the first trial was a narrowing one). If children were influenced by the feedback they received, we would expect more children who received consistent feedback to choose the useless/narrowing clue on the following trial than those who heard contradictory feedback. The distribution between useful and other clues seems the same, regardless of the feedback given. No trends seem caused by feedback, and so I concluded that children were not learning from the feedback they received, which is what would be expected if children were having difficulty understanding why some clues are more useful than others.

*Comparison between tasks.* To compare between the two games I scored children as performing correctly or incorrectly. I allowed children to make one mistake in the cones game (the adjusted strategies). This means that by selecting indiscriminately between the two strategies there is a  $5/16$  (0.3125) chance of correct performance. I made comparisons separately with the useless and narrowing trials, because these differed in difficulty. To make a fair comparison against cones I defined correct performance as choosing the useful clue on both trials. The chance of doing this is  $1/4$  (0.25) for each pair of trials. These are comparable for my purposes, although performing correctly on cones by chance is slightly more likely (I divided the probabilities to assess their compatibility, as in Table 13 (Chapter 4), to give the figure 1.25: cones, 0.3125, divided by clues, 0.25). The frequencies for success on the cones and clues games are shown in Table 17. Using 2-tailed binomial tests there is a borderline significant difference between performance on the useless clues trials and cones,  $N=17$ ,  $k=4$ ,  $p=.05$ , but there is no difference between narrowing trials and cones,  $N=15$ ,  $k=7$ ,  $p>.999$ .

**Table 17: Clues tasks compared to adjusted cones strategy**

		cones	
		incorrect	correct
useless clues	incorrect	16	4
	correct	13	11
narrowing clues	incorrect	22	8
	correct	7	7

I described above why the useless clue trials might be easy and so I focussed on the narrowing trials to decide whether children can identify the information which will disambiguate a set of potential referents. As children find this no easier than cones, a task that we know they find difficult, I concluded that identifying the piece of disambiguating information from the two choices is as hard as deciding which strategy to use on the cones game. There was an alternative explanation for why the narrowing trials are more difficult than the useless. Due to the nature of the clues, the picture set in the narrowing trials was visually more complex than that in the useless trials. This extra information processing demand might have caused the children to find these trials more difficult and cease to pay attention to the information available from the two clues. I argue that this is unlikely to have been the main cause of the difference between the two types of trials: children had played a game with a similarly complex picture array in the stop game. Although children did make errors in the stop game by stamping on the narrowing clue in preference to other parts which were revealed before the disambiguating part, the vast majority of the errors were not of this type (45:13 late: narrowing in Experiment 7). However, I note this problem and suggest a procedure which would rule out this possibility and develop my findings from this experiment in my proposals for future research (Chapter 6, Section 2.2).

### 3 Discussion of Experiment 8 and Summary

In this chapter I looked at the child's handling of ambiguous information, out of the context of strategy selection. The children in Experiment 8 were able to select a useful clue rather than a useless one, to some extent (although their performance was not at ceiling). However, I argued in the introduction to Experiment 6 that performance on the narrowing trials was critical. Children's performance on these trials was not as good as that on the useless trials, nor was there any difference between success on these narrowing trials and on the cones game. The finding that children's choice of clues on the narrowing trials (unlike the useless trials) did not differ from chance lead me to conclude that children do indeed have difficulty identifying what information will disambiguate an ambiguous message.

Might it be that children did not think it was important to choose the more useful clue of the two offered to them? The aim of the game, as explained to the child, was to identify the target picture, and to do this the child had to choose something to find out about before making an interpretation. If the child did not appreciate that this was the aim, or that they were supposed to choose a clue that would improve the accuracy of their interpretation, then it would be wrong to claim that they are unable to select between narrowing and disambiguating clues. However, their good performance on the useless trials shows that they can choose systematically between two types of clue. On these trials they are acting as if they understand that the aim of the game is to choose a clue which will improve their interpretation. Given this good selective choice of clues, I conclude that the unsystematic choice on the narrowing trials is due to a problem differentiating the clues, i.e. what they can learn from these clues, rather than a difficulty with the aim of the game itself.

If children have difficulty identifying what kind of information would be useful to resolve an ambiguous message, then this would clearly lead to difficulties with certain

strategy selection tasks. Most obviously, the child could not be expected to ask a question which specifically targets the missing information if s/he is unable to identify this. This interesting finding suggests that young children might have problems with certain information processing aspects of ambiguous information, which will cause difficulties with tasks which require them to handle ambiguity.

This argument raises an interesting problem. There are tasks which do not demand that one seeks specific disambiguating information, but just that one recognises that the ambiguous information is limited. Indeed, my cones procedure can be interpreted in such a way which does not obviously require one to identify what information would disambiguate the message. In Chapter 4, I argued that the relatively good performance on the stop game meant that monitoring certainty and uncertainty cannot be the only difficulty children have with ambiguity tasks. A child who can monitor his/her certainty should be able to recognise informative messages as allowing one to feel certain about the referent. Put simply: if one is certain then one should make an interpretation and if not, one should use the more cautious response of looking under the cones first. There is no obvious need to identify what information would disambiguate the message. However, the younger children I tested have consistently found the cones procedure difficult. Were they failing to monitor their certainty effectively, even though we have seen that they are relatively good at doing this in Experiment 7? I suggest that a resolution of this problem can be found by linking my findings from Experiment 8 (useless clues) with the mistakes children made on the cones game.

When children fail the cones game they do not do what we might have expected from the established literature: make interpretations of both ambiguous and unambiguous messages. Instead many children use an inappropriate mix of the two strategies (11/26 (42%) children in Experiment 3, 17/41 (41%) in Experiment 7 and 14/44 (32%) in Experiment 8).

Why would someone use the seeking strategy to respond to an unambiguous message? Surely one should know that when there is certainty the more confident response is appropriate. Remember that when children played the useless clues game they failed to discriminate between clues which would only tell them something more (the narrowing clues) and clues which would disambiguate the message. Their difficulty here is in deciding what information will best improve the accuracy of their interpretation. If children do not understand what information is needed, this will have implications for their choice of an appropriate strategy when they hear an ambiguous message. I argue that selection of the most appropriate response, that is a cautious or confident strategy, requires not only that you recognise whether you are certain or not, but also tied up in understanding whether a strategy is cautious or confident is the knowledge of what information it will provide and how this relates to your current situation. I am claiming that it does not make sense to think of the child as having a confident and cautious strategy, as s/he does not understand how these strategies relate to the information s/he has already. If the child has two responses to choose from but does not see them as differentially cautious, then some children will use a mixture of the two strategies just because they have them available. Perhaps one of the aims of the game (as the child sees it, and the experimenter has explained in introducing the game) is to use both responses. This is an important move in my thinking about strategy selection: that it needs not only recognition of certainty but also understanding of why a particular strategy might be cautious or not. The results from the useless clues experiment suggest that the latter is a problem for young children. Hence, the consistently poor performance on the cones game is in keeping with children being unable to work out why they experience feelings of uncertainty on hearing some messages (or seeing some pictures) but not others.

In the light of this thinking on how one must integrate awareness of certainty or uncertainty with the understanding of what is problematic about the information available, I return to develop my explanation of why the narrowing trials on the clues task are difficult. As I argued in the introduction to Chapter 4, my aim in these chapters was to remove the planning aspects of handling ambiguity, and to explore whether the subcomponents of recognising certainty and identifying disambiguating information might cause children specific problems. Certainly that is one interpretation of the useless clues results: children have specific difficulty identifying what would disambiguate potential referents, and this will cause major problems in their ability to handle ambiguity. However, in keeping with the explanation of how I might explain difficulty with the cones task, perhaps there are aspects of planning which are inherent in this procedure. The global planning decision of how to respond to an ambiguous input is removed from this task, but in asking the child to decide what they need to find out, the question of why one is trying to find this information out, is integral to the task. Once again, I can only suggest future research to support this proposal, but my suspicion is that children should perform well on a task which asks only “How are these four pictures different?” rather than “What do you need to find out?” the latter in the context of identifying a target picture. Indeed, in the introduction to this chapter, I drew this distinction between the ability to physically discriminate between the pictures and to discriminate between the information available from the clues. I discuss a new procedure concerned with this suggestion in more detail in the General Discussion, Section 2.2. To conclude this chapter on children’s difficulties identifying disambiguating information, I claim that they do have difficulty with this. The proposal that this is because this task requires one to understand the relationship between the information held, the goal of the task

and how this goal can be attained, seems well suited to accommodate the results of the work in this thesis.

## **General Discussion and Future Work**

### **1 Summary**

My overall aim in this thesis was to explore children's abilities to handle ambiguity. I wanted to move the emphasis away from reflective and evaluative tasks, which dominated the established literature. Based on my reading of the ambiguity and executive function literatures, I explored children's ability to use alternative strategies to handle ambiguity, and investigated whether they had difficulties in planning a strategy to resolve the ambiguity they faced. My experimental work fell into two sections: I was first concerned with attempts to reveal abilities in young children which may have been overlooked by the earlier literature; and secondly I attempted to identify which aspects of ambiguity tasks, or of handling ambiguity, might cause young children particular problems.

#### **1.1 Using different strategies to respond to ambiguity**

For the approach taken in the first section (Chapters 2 and 3), I judged that the established literature concerned with ambiguity might seriously underestimate children's competence. Three observations lead me to this possibility:

- that the literature was over-reliant on verbal and evaluative tasks, which place additional metacognitive demands on children confronted by ambiguous input.
- that asking children to evaluate ambiguous messages or pictures out of context (i.e. where this evaluation did not progress the child towards the goal of resolution of an ambiguous input) was common. Children's performance might improve if they were asked to deal with ambiguous input as they encountered it, within the context of a task, rather than in an abstract task removed from their goal of interpreting the input.



- that adult handling of ambiguous input does not use one appropriate response common to all situations. Instead, adults might explicitly identify the input as ambiguous, make a tentative interpretation or seek extra disambiguating information. I wanted to give children the chance to use these functional strategies to handle ambiguity. Although some researchers had encouraged children to ask questions when input was ambiguous, I argued that their negative findings might be due to the specific nature of the task (that making an interpretation might be more appealing than asking a question). I wanted to explore whether certain strategies might be easier for children to use than others.

In the first two experimental chapters of this thesis (Chapters 2 and 3), I focussed on this possibility that children's competence was underestimated by the established literature. I offered children two broad alternative strategies to handle ambiguity: making tentative interpretations and seeking extra information. I explored their ability to make tentative interpretations first. That is, despite their choice of one potential referent, were children open-minded about which referent might be the intended one? I found that 5- and 6- year olds' ability to revise interpretations was excellent. Not only was their commitment to an interpretation (measured by their willingness to change their mind on hearing a second piece of information) appropriate to whether the information was ambiguous or informative, but also, when a revision involved using information from the first ambiguous message they used this to select the appropriate final referent (Experiment 2).

Despite this good performance, I recognised that it would be premature to judge from this that children were making tentative interpretations at the outset. The interpretations the children made were certainly being treated as if they were tentative and, objectively, one might want to label an interpretation which is open to revision as a tentative one. However,

my focus was on what the interpretation is like for the child: what s/he understands about the limitations of ambiguous input. I needed to know more about the child's abilities before I could claim that the child him/herself was making a tentative interpretation – i.e. one which s/he knew at the time of making might need to be revised. Previous research concerned with confidence judgements of the knowledge to be gained or adequacy of ambiguous messages did not lead to optimism about children's understanding. Because of my desire to move away from abstract evaluation tasks, I did not ask the child to make confidence judgements about the interpretations they made. Instead, I chose an indirect route to inform me whether children's interpretations were tentative by introducing the second of the strategies identified above.

I reasoned that if one was about to make an interpretation which was genuinely tentative, then an alternative strategy of seeking extra, readily available information should be more appealing. This would improve the accuracy of one's interpretation, and allow one to avoid making a potentially incorrect (tentative) interpretation. In the cones game, I introduced a seeking strategy, which was highly compatible with the goal of the game. I also deemed it easy to use, not only because of its objective simplicity (just looking under the cones you were considering as potential hiding places), but also because the young children in my experiments commonly used this response instead of making an immediate interpretation. Despite this, few of the sample of younger children were able to seek extra information appropriately, and they were outperformed by an older group of children.

If children are unable to see merit in seeking extra information when making an interpretation, I argued that it was unlikely that they were aware that this interpretation might be wrong (in the case of Experiment 3, the interpretation was as likely to be right as it was to be wrong). Hence, although children revised their interpretations of ambiguous messages on

contradiction, this was better thought of as prompted by this as a correction, rather than because they had made genuinely tentative interpretations at the outset.

In Experiment 3, the younger children used an inappropriate mix of the two strategies. This was especially interesting because one characterisation of young children's difficulty suggested by the literature is that they tend to make an immediate interpretation, without considering the full range of potential referents. If children reach premature closure as suggested by Acredolo and Horobin (1987), then we would expect to see a strong tendency to choose a referent, rather than seek extra information. This would not be the direct result of a failure to understand why certain strategies are appropriate, but rather that having found one referent which meets the (ambiguous) description, the child fixes on it, feeling confident that s/he has found the intended referent. Interestingly, the finding that children show different non-verbal responses (such as reaction times) to ambiguous messages is also problematic for the premature closure suggestion (perhaps without employing an implicit/explicit model of how children handle ambiguity). In fact, if anything, we might expect to see faster reaction times when there are multiple potential referents, although admittedly only if the child was considering the items serially. As my results contradicted this type of explanation, I looked to confirm my suspicion that children did not always make hasty interpretations of ambiguous input, in Experiments 4 and 5. Drawing on two literatures, I developed two new tasks in which the child selected what would have been the best strategy to use.

There are various ways in which different literatures might characterise the tendency to make an interpretation too early. From the literature on executive function, I used the distinction made between performance and competence errors (see Russell, 1996). Thus, we might describe children as (possibly) failing ambiguity tasks because they are unable to resist

making an interpretation. Even if children encounter more than one referent which meets the description they make their prepotent response – to choose one.

The literature on counterfactual reasoning gave me more reason to think children's performance on the tasks in Chapter 3 would improve. When adults experience events that are negative they are frequently prompted to generate counterfactual events which would have led to a preferable outcome (Roese, 1997). It has been suggested that adults dedicate extra cognitive resources to generate counterfactual alternatives when in negative circumstances. I hoped that if children were asked to choose a strategy with hindsight, after a negative outcome had occurred, then they might draw on these proposed extra resources and identify a more satisfactory response to the ambiguous input.

In Experiments 4 and 5, I used two tasks in which children were asked “What should X have done?” hoping to remove the problem of inhibiting an immediate, prepotent interpretation response to ambiguous input and increase the cognitive resources children might employ in thinking about the problem counterfactually. Despite my optimism that children might find these retrospective tasks easier, their performance remained poor. They did not systematically choose a seeking response, neither when it was presented as “ask” for more information nor in the simple cones procedure where the appropriate response to ambiguous input was to look under the cones before making an interpretation.

## **1.2 What is difficult about handling ambiguous information?**

Given my failure to facilitate children's use of alternative strategies to handle ambiguity, I decided to explore whether I could identify aspects of our ambiguity tasks that might be easy or difficult for children. I identified two broad skills which would be needed to

handle ambiguous information:

- knowing when to seek extra information.
- knowing what you can find out to differentiate the referents.

I first turned my attention to knowing when, which I saw as a very general comprehension monitoring skill. In order to know whether you can make a confident interpretation or not, you need to have some measure of the certainty or uncertainty you feel. But a feeling of uncertainty alone would not allow you to handle ambiguity. You also need to have an idea of what you need to find out – or at least that you need to find something else out (which does not necessarily follow from knowing that you are uncertain) and also, the consequences of the strategies available to you. However, I saw this uncertainty monitoring as a necessary skill for competent handling of ambiguous input. In Chapter 4, I used a new procedure, in which I removed the explicit need for strategy selection, but instead focussed the demands on judging when one knows. The child had only to resist making an interpretation until s/he knew which referent was intended, i.e. until s/he saw a disambiguating part of a picture.

I ran two experiments using this procedure. In the first, I compared a risk group and a speed group. The former was told that winning a sticker at the end of the game was dependent on their finding the correct targets. Children in the speed group were told that they would automatically receive a sticker for playing the game, and were alerted to the need to play the game as quickly as possible. The risk group were more likely to wait for redundant information before making an interpretation than the speed group, and the latter's performance was more accurate. The children tested were relatively old, which may have led to unusually good performance. However, when I compared the speed procedure with the cones game, in Experiment 7, I found that performance was better on the former. I

acknowledged that problems with the chance baselines of these two games meant that I could not make a very strong claim about this. Furthermore, children's abilities to respond to their certainty were not perfect, on many occasions children delayed their response past the disambiguating piece of information. However, I reasoned that when handling ambiguity the child has to recognise when s/he feels uncertain and make an appropriate response. The stop game was designed only to test whether children might be able to monitor their (un)certainly sufficiently well to be able to recognise the uncertainty resulting from ambiguous input. Their success in delaying responding until after the disambiguating piece of information was revealed suggested that there was no reason to suspect that a difficulty in monitoring uncertainty was the main cause of children's difficulty with ambiguity tasks.

In Chapter 5, I moved to the second of the skills I had identified as possible components of handling ambiguity. I had described this as knowing what would disambiguate a problematic input. My argument was that even if children knew whether the input left them feeling certain or uncertain (as I concluded they were doing in the stop game) they might still have difficulty selecting an appropriate strategy to deal with the problem, if they did not know what would help them resolve the ambiguity. Thus, my question was whether children could choose the information which would disambiguate an ambiguous message. My results from Experiment 8 showed that this was a problem for young children. Importantly, they succeeded on a version of the task where they had to discriminate useless (uninformative) information from disambiguating information. However, they failed to choose information that fully disambiguated the message rather than that which only narrowed their potential range of referents.

As I argued in the discussion of Chapter 5 (Section 3) it is problematic to claim that young children's difficulty with ambiguous information is caused by a narrow inability to

discriminate the types of information that would disambiguate a message. This was because children also found my cones game difficult, which has no immediate need to discriminate types of information. Rather, I proposed that their difficulty might be better thought of as understanding why they experience uncertainty and what they can do about it. There are two ways of describing this problem, each of which approach the problem from different sides, but I believe both describe the same basic difficulty. Either we could characterise children as having difficulty “understanding” why the information they encounter is ambiguous, or we could think of the children as lacking understanding of what can be done to remove the uncertainty they feel. I believe the second description is more useful in thinking about why children have difficulty with ambiguity. Firstly, it recognises that children do feel uncertain when they encounter ambiguous information. Secondly, it allows us to include children’s difficulties in planning a response as a key part of their difficulty. Essentially, I am returning to the type of executive competence difficulties proposed by Russell. I suggest that although we can scaffold the problem of handling ambiguity for a child and improve their performance (as in the pictures and stop games), tasks such as the clues game ask children to plan what needs to be done to resolve ambiguity. I suggested that we might not be able to remove entirely the planning aspects from the useless clues task as it stands, even though the need to plan a final response output is removed. Deciding what information one needs to find out requires that one understands what one is trying to do and why. This is in contrast to identifying only in what way a set of pictures differ (I develop this into a proposed procedure in the next section). In this way the useless clues result is one way of showing how such a problem with understanding how to remove the uncertainty caused by ambiguity would manifest itself.

This redescription of the child's difficulty in "understanding ambiguity" has developed from my application of theories of executive function as well as the ambiguity literature. The inclusion of the executive literature allowed me to target what children could do with ambiguous information, rather than focus on whether they could identify it as problematic. As their problems generally persisted, but they also showed good performance on the stop game, I was able to begin to describe why they find it difficult to evaluate ambiguous input as poor. In particular I was able to suggest planning as a broad difficulty, which encompasses knowing what will remove your uncertainty and how (or whether) to get this information. As in much of the literature, my use of the term planning is vague, but I hope it characterises the problem children might have, even if as yet I cannot give an explanation of how this ability might develop or be put into effect. At the end of my introduction to the executive function literature (Chapter 1 Section 4) I suggested that it was possible, but unknown, whether using the ideas of executive function to explore ambiguity might feedback into how the former area is conceptualised. I think that there is potential for this, in thinking about the fractionation of executive abilities. Although I have seen benefit in separating problems with inhibition and prepotent responses from tasks, my argument that planning is integral to the whole problem of handling ambiguity successfully is more in keeping with Russell's account of executive competence, than approaches which seek to identify factors comprising executive function. Rather than the executive functions being end stage coordinating skills, children's difficulty with the clues task suggests that these difficulties might prevent children succeeding even on the subcomponents of a task, if these remain goal-directed.



### **1.3 Links to the established literature**

To end this section, I will illustrate how my portrayal of children's difficulties can help us to understand the findings of the established literature, by considering a few studies in detail. I will use my findings that children might successfully monitor their (un)certainty, while remaining ignorant of what can be done to remove the uncertainty caused by ambiguous input. Although the results from the stop game gave us good reason to believe that children were relatively good at monitoring (un)certainty, children's failure on the cones and useless clues games in particular led me to suggest that children are unable to plan what can be done to resolve the problem they have encountered.

Firstly, I return to Bearison and Levey's early work, in which children heard ambiguous and informative questions (Bearison & Levey, 1977). For example, children heard "Jane got a bicycle for Christmas and Mary got a new coat. What did Jane (informative)/she (ambiguous) get for Christmas, a bicycle or a new coat?" Children had to answer informative questions, but if the question was ambiguous, they had to identify it as such and explain why. I have argued that even if children felt uncertain when they were asked the ambiguous question (and in this study extended response latencies suggested that children did feel uncertain), they might not have been able to work out what would remove the uncertainty they felt (in this case, finding out whether the speaker means Jane or Mary). If the child cannot do this, s/he would not know whether the uncertainty is the result of something about the message, or the result of something else, for example, not listening carefully or perhaps the message is just too hard for the child to solve or impossible to solve. Similar problems can arise in other situations where people might feel uncertain. One could imagine a child, asked by a teacher the answer to a sum, who is uncertain as to the answer. This might be because s/he has not heard the sum completely, because the sum is too hard for the child to

solve (perhaps s/he does not yet know a certain mathematical term, such as division), or because it is an impossible question (among other possibilities). In another example, an adult trying to solve a cryptic crossword might feel uncertainty about one of the answers.

Typically, s/he would attribute this to a lack of skill or understanding of how this clue works on his/her part. However, it is possible that the clue is a misprint, or even a badly constructed clue, in which case the problem is with the input. In an interesting parallel, note that if the adult (unless perhaps they are an expert at crosswords) cannot see a way of removing the uncertainty s/he feels, s/he is likely to fall back on his/her normal criterion: “this clue is too hard for me”, ignoring the alternative possibilities.

Knowing how to remove the uncertainty one feels enables one to say why the input is problematic. The child in the Bearison and Levey type task cannot identify a route to remove the uncertainty s/he feels and so the task of judging the adequacy of the input they hear is an impossible one. There is an important difference between the child identifying that she feels uncertain and whether the message itself was problematic. Without understanding what will remove her uncertainty, and having no ground on which to base the evaluation of the message, it might make sense to the child to revert to an alternative criterion: can I give an answer? In Bearison and Levey’s task, there were two possible answers to the question available (in this example either “a bicycle” or “a new coat” might be the correct answer) and so, in the absence of being able to see a way to remove the uncertainty, the child might answer that this was a good question, because s/he could give an answer. This use of a different criterion for evaluation is particularly obvious in tasks where the choice of responses to ambiguous and informative messages are asymmetric; if the child cannot manage to judge whether certain messages themselves are inadequate, then there remains an easy option of making an interpretation. However, even in tasks where the child is asked only

to evaluate both ambiguous and informative messages, similar problems could arise. Because the child cannot work out why certain messages leave him/her uncertain, s/he needs to use some other criterion to evaluate them: can I find a suitable referent? is a plausible one (although, as I discuss in connection with Ackerman's work below, it is not the only one).

In other message evaluation tasks, young children not only wrongly evaluated the inputs they heard, but also showed a tendency to blame the listener when a misinterpretation occurred (Robinson & Robinson, 1977a). I suggest that when one can confidently identify the input as problematic, this is because one knows how this information could be improved. For example, if an adult sees a partial view of an object and cannot identify it, the adult recognises that a different view would allow identification. In the crossword example, if the paper were torn so that only half the clue could be read, the adult would know that the rest of the words were needed to solve the clue. There would be no question of blaming oneself, the reader, for the difficulty in interpretation. However, I contrasted this earlier with the uncertainty that arises from a mistyped crossword clue. In this case, the adult is unlikely to recognise that seeking out a corrected version of the clue is one way of improving the input and instead, s/he is most likely to attribute blame to his/her own lack of understanding. A young child who feels uncertain on hearing an ambiguous message and is asked to attribute blame following misinterpretation of ambiguous messages has no way to judge between inputs that are themselves inadequate (about which something could be done), and those that are adequate, but s/he cannot interpret. However, there is an alternative strategy for blame attribution staring the child in the face. In blame tasks, the question about blame must be asked after an interpretation has been made and been revealed as right or wrong. The listener can, rightly, be described as having chosen the wrong referent, even though because of the ambiguity of the message, this was not his/her fault. As the child now knows that the listener

has chosen the wrong referent, and is unable to work out how the message might have been improved, selectively attributing blame to the listener when the communication has failed might seem to the child to be a reasonable strategy to use.

I have suggested that children do recognise feelings of uncertainty or certainty, but cannot work out what could be done to the input to improve it and hence whether the uncertainty relates to the message. This fits well with Ackerman's findings (Ackerman, 1981). Children found it easier to allocate ambiguous messages to a "selfish" rather than a "stupid" character. A child who has to attribute a message to a "nice" or "selfish" character, might focus on whether the message allows them to feel certain about the intended referent. A selfish character, who does not want you to find the right target, will give bad messages that cause you to experience uncertainty. There is no need for the child to consider why these messages are bad, or how s/he could remove the uncertainty. Thus, the child can successfully allocate messages to the two characters in this condition, based only on his/her feelings of uncertainty. Why might children find a version of the task where they must decide whether messages come from a "stupid" or "smart" speaker difficult? In this condition, the task might be complicated by trying to understand why the message is bad (which I have described as knowing what one could do to improve it). As before, if one starts to wonder about why the uncertainty has arisen, there are various possible causes (a problematic message or lack of ability on the part of the listener, for example). This task might be more similar to the straightforward message evaluation tasks, in which children, confused by their lack of understanding of how they could remove their uncertainty, are nevertheless able to make an interpretation of the ambiguous message. What is most important for my argument is not why children would selectively base their ratings on their feeling of uncertainty in the "selfish" trials, but that they should be able to categorise messages as good or bad if the certainty or

uncertainty is what they are attending to. Like Ackerman, I believe that children's performance will be affected by how they treat the task of judging the question (based on their feeling of uncertainty or the quality of the message), but my interpretation of what children are doing when they succeed on his task differs. His suggestion is that when the performative demands of the task are removed, children can attend to the locutionary aspects, that is they can evaluate the ambiguous and unambiguous messages accurately. My suggestion is that the good allocation of messages does not necessarily reveal success evaluating ambiguity, but instead could result from children changing to focus on their certainty or uncertainty, rather than the quality of the message itself.

Thus, I suggest that children who cannot work out why they feel uncertain might evaluate messages or questions using other criteria, and that children might sometimes be able to identify input as problematic if they are focussed only on their feelings of uncertainty. This seems a plausible explanation of performance on the evaluation type tasks. But why do children not use their feeling of uncertainty to direct them to the more cautious question-asking response in other studies (e.g. Ironsmith & Whitehurst, 1978a, 1978b; Cosgrove & Patterson, 1977)? For this, I use the same thinking as that used to explain why children might find my cones task difficult. Namely, that if the child does not understand how to remove the uncertainty s/he feels, it is a mistake for us to think that seeking more information is a more cautious response (for the child).

In Ironsmith and Whitehurst's task (1978a), children tried to identify pictures from an array. If they could not (when the message was ambiguous) they were directed to ask questions. Imagine the child in this task, who knows that the aim is to identify the correct picture and that s/he can either choose a picture or ask a question. S/he hears an ambiguous message and feels uncertain about which picture to pick. Because of this, s/he might consider

the other option – to ask a question. But my results from Experiment 8 suggest that s/he would not be able to identify what s/he should ask about, and because the child cannot work out how to improve the information s/he has, s/he would not understand that asking a question would be more effective. Thus, there is no way for the child to decide which of the two options (ask a question or choose a picture) would be more effective in achieving the goal. All we need to suppose to explain these results is that the child finds it easier to choose a picture than to ask a question. There are many reasons why this might be so: asking a question might be more demanding; it might be more fun to choose immediately or involve less of a loss of face; and choosing is certainly a quicker way of playing the game. More support comes from the failure of modelling questions to improve young children's performance (Ironsmith & Whitehurst, 1978b, Cosgrove & Patterson, 1977). In particular, Ironsmith and Whitehurst report an observation that if children did learn to ask a question, they often mimicked the entire modelled statement, "It must be one of these two. They're both round and big. So which one?" rather than employing the essence of the strategy itself. In my cones task, the seeking response is so simple that we might expect children to use it easily. But, as with these question asking tasks, I suggest that they did not understand why it was appropriate, and so although many children used this response, they did not employ it selectively to disambiguate problematic messages.

In examining these examples from the established literature, I hope to have shown that the mistakes children make are to be expected if children do not understand how to handle ambiguous input. Importantly, their tendency to make interpretations need not result from overconfidence in the information to be gained from ambiguous information, but could equally well occur when their inability to plan a successful strategy to deal with the problem means that they cannot differentiate between the effectiveness of the strategies they are

offered. One of the most satisfactory outcomes of my proposed description of children's difficulties is that it allows us to accommodate the findings from studies of non-verbal behaviour: that children clearly exhibit different non-verbal behaviour when confronted by ambiguous, rather than informative input (e.g. Plumert, 1996). The observed behaviours suggest that children experience uncertainty, but I have found no reason to suppose that the child understands what should be done about this uncertainty. Furthermore, my proposed explanation would lead us to expect that in some cases children might be able to make 'appropriate' responses to ambiguity tasks based on this uncertainty (e.g. Ackerman, 1981; Sodian, 1988). Thus, I suggest that children's difficulty is not in recognising that there is a problem, but in understanding why this problem has arisen and crucially what follows from this: how this problem can be resolved.

## 2 Future Work

In this section I present two specific areas for future research, which develop procedures I devised for this thesis. I also discuss how the work presented here should inform future thinking about the more general development of children's ability to handle ambiguous input.

### **2.1 Modified stop game**

Children's partial success on the stop game, presented in Chapter 4, raises questions which need to be answered by future work. Most importantly all my tasks have been set up so that it is legitimate to be overcautious. You could ensure you met the goal of the stop game by waiting on every trial until the whole picture has been revealed and similarly succeed on the cones game by always choosing to look. To further our understanding of children's

ability to handle information that is either partially informative or informative, we should investigate whether they can identify precisely when an accurate interpretation can be made.

My aim in this new procedure would be to include a disincentive for being overcautious and to make closer comparisons between the stop game and other tasks (i.e. by changing the chance baseline). The game would be a simplified version of the stop game in which there are only two windows. The chance of stamping on the correct window (assuming that children do not always wait until both windows are opened) is thus 1/2. This is the same as the chance of being correct on any one cones trial and so comparisons between tasks would be more straightforward. To include a disincentive children would be differently rewarded for interpretations made on the first or second window: a correct interpretation made on the first window would win two stars, a correct interpretation made on the second window would win one star and an incorrect interpretation, on either window, would win no stars. Clearly, piloting would be needed to check that children could master this system of rewards, but given the ease with which children (albeit perhaps slightly older or more mature ones) took the rewards into account in Experiment 6 (the first stop game) there is reason to be optimistic. I would check that children understood the rewards by asking them to reward a puppet who plays the game first. In experimental trials, the disambiguating piece of information would be revealed by the first or second window. Children who stamp on the first window only when this would enable them to get more stars but wait until the second window when appropriate would reveal an appreciation of which piece of information allows them to know the intended referent.

## **2.2 Children's difficulty with disambiguating information**

A second area for development is suggested by the useless clues experiment in the final experimental chapter. I have argued that children played this game competently because



of their good discriminating performance on the useless trials. Future research is needed to explore further the idea that children might find this task difficult because they are having to think about why the information is problematic and what could be done about this: these are the broad planning difficulties that I have suggested are children's central difficulty in handling ambiguity. I make three proposals of new experimental work, which would further inform us as to children's difficulty identifying disambiguating information.

- 1) Firstly we need to check that children's poor performance on the narrowing clues trials is not the result of the more complex picture array that they see (as mentioned in Chapter 5, Section 3). It might be that increased information processing demands are causing the child difficulty on the task, rather than understanding which piece of information will disambiguate the message. In the hope of ruling out this possibility a new version of the task would use the same set of pictures for useless trials for half the children and helpful trials for the other half. Each set of pictures would have three features which could be useless, narrowing or disambiguating and on each trial there would be one feature of each type. For example, a set of pictures could include four people, all with the same colour hat (useless), two with red coats, two with blue (narrowing) and all with different colour bags (disambiguating). Trials would ask the child to choose between the useless or disambiguating clue ("Do you want to find out about the hat or the bag?") or between the narrowing and disambiguating clue ("Do you want to find out about the coat or the bag?") If children's difficulty was caused by the complexity of the picture set then we would expect these trials to be equally hard. If the difficulty is a problem understanding about disambiguation then we would expect the same results as in Experiment 8, i.e. that the useless/disambiguating trials would be easier than the narrowing/disambiguating trials.

- 2) In Experiment 8 my aim was to make the choice between pieces of information as simple as possible and to rule out other complications of the task. It would be useful to generalise this finding to other tasks and types of information. In a new task the problem could be placed in a more “real world” setting, perhaps by telling the child we are making clues for another child to find a target and giving them the choice of which would be the best clue. (Similar contexts have been used in other experiments, such as Jackson and Jacobs, 1982, where children were asked to generate clues for an imagined classmate to hear and by Beal, 1990, who read children stories containing inconsistencies or missing information and asked them to help “fix up” the stories so that they would be easier for another child to understand.) Also children could be asked to make choices between different types of information, rather than the idiosyncratic parts of a picture (hats, bags etc.). In a new task the child would see a set of locations, and would be given a choice between different pieces of information which might disambiguate them. In a trial where, for example, hiding places are under a red square, a red triangle, a blue circle and a blue star, the child would choose between colour or shape. The results from my helpful clues trials predict that children would not systematically select the disambiguating information. In designing this procedure, it would be necessary to take note of Plumert’s recent work on children’s communication about spatial location. In her work, young children (3- and 4- year olds) are shown to prefer certain types of information when trying to give disambiguating information. They were more successful in giving adequate descriptions when this involved saying the target was “in” a location, rather than “next to” (Plumert & Hawkins, 2001). Furthermore, in a second set of studies (Nichols-Whitehead & Plumert, 2001), children preferred to use colour and identity rather than location information to give

instructions. Despite children's ability to use certain types of information to give disambiguated descriptions of location, they needed prompting to give the sufficient information: in tasks where children had to give directions to find a target they needed prompting on over 70% of trials, to give "more" information about the location. So this work does not question the finding that children do not spontaneously understand what information will disambiguate an array.

- 3) The most important development of the clues game is to test my suspicions about the global planning difficulties inherent in asking a child about what s/he needs to find out. I proposed that asking a child only to describe how pictures were the same or different might be easy, if it is done completely out of the context of trying to respond to an ambiguous message. In Experiment 8, I asked children to describe the colours of the various features, to ensure that they had noticed them. However, this process of stating that, say, two ladies had blue hats on and two had red hats, did not enable the children to reject the narrowing clue. Children should be able to answer correctly "How many have red hats?" and "Which ones have the same colour hats?" as this question is out of the context of disambiguation task. I predict that children, shown a set of four pictures as in my narrowing trials, might also find a question "How are these [indicating all four ladies] different?" easy, and identify the disambiguating feature rather than the narrowing one. Yet a comparison group (who were trying to disambiguate a message) would find the question "What do you need to find out about?" difficult. Future work concerned with how children learn to employ appropriate strategies to handle ambiguity could test whether answering the "How are these different?" question facilitates answers to my standard clues question and whether training on this could transfer to other ambiguity tasks in which one has to seek disambiguating information.

### **2.3 Broad research implications and learning**

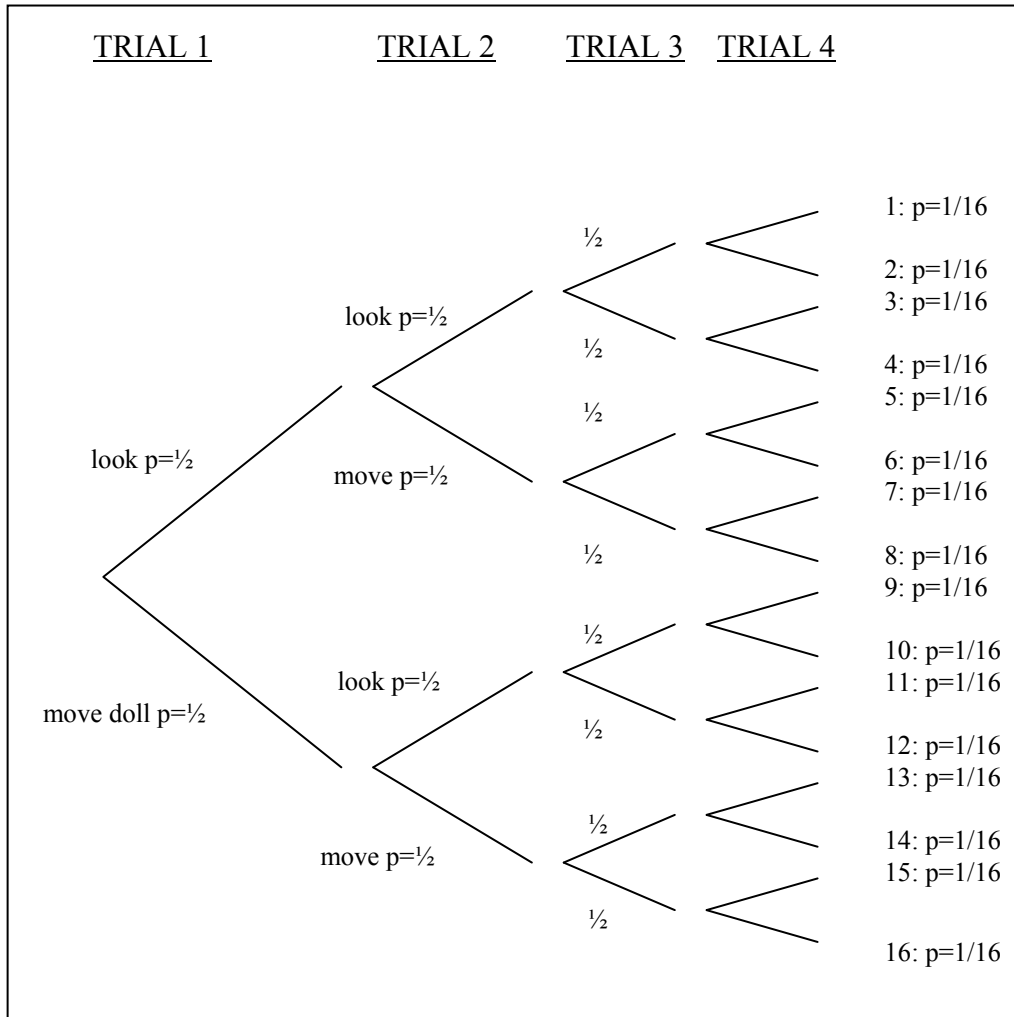
My findings show that children's problems with ambiguity tasks are genuine, and suggest that this is the result of a cognitive problem, that of understanding how one can remove the uncertainty one feels. As described above there is still experimental work to be done which would allow me to state even more precisely what children find difficult about ambiguity. Given the evaluative nature of much of the established literature, I needed to check that ambiguity does present genuine problems for children. Having shown that children had difficulties with tasks which did not demand a verbal response and were not reflective, and that their competent understanding was not being masked by a performance error, this is something we can be confident in. Moving on from here, it is an important question how children come to learn to use strategies effectively. In my experiments children have been most successful in the procedures where the experimenter has scaffolded their actions: in the pictures task (Experiments 1 and 2) when the child's decision making process was entirely structured by the experimenter; and in the stop game (Experiments 6 and 7) when the child did not have to choose between strategies and the progress of information was out of their control. Children's everyday encounters with ambiguous information might provide us with examples of children's use of well-rehearsed strategies, which give them a way into understanding why such strategies are appropriate. For example, in a common classroom situation, where someone asks a child to fetch one of two children with the same name, the child does not simply go and fetch the first one they encounter who matches the ambiguous description. More commonly they might hesitate and say "which one?" On the surface this is an effective seeking strategy used to disambiguate the message the child has heard. But as I have rejected the premature closure explanation and seen that children were able to use different strategies but not selectively, the child's behaviour in the classroom example does

not necessarily mean that s/he understands why this strategy is appropriate. Future research should explore the potential for these strategies to be transferred to other situations, whilst being wary of false positives when children employ strategies but do not realise their consequences.

In conclusion, my empirical findings have supported the claim that children have genuine problems handling ambiguity and offered some directions as to why these problems might arise. As importantly, I have set the stage for a shift in research on the development of children's abilities in this field, by rethinking what might cause them difficulty and introducing the idea of planning how to handle ambiguity. Finally, I speculated that certain strategies, used flexibly and effectively by adults, might be adopted by young children and over time facilitate an understanding of why ambiguous information is problematic.

## Appendix A: The probability of answering at chance on experimental procedures

### 1 Cones Procedure

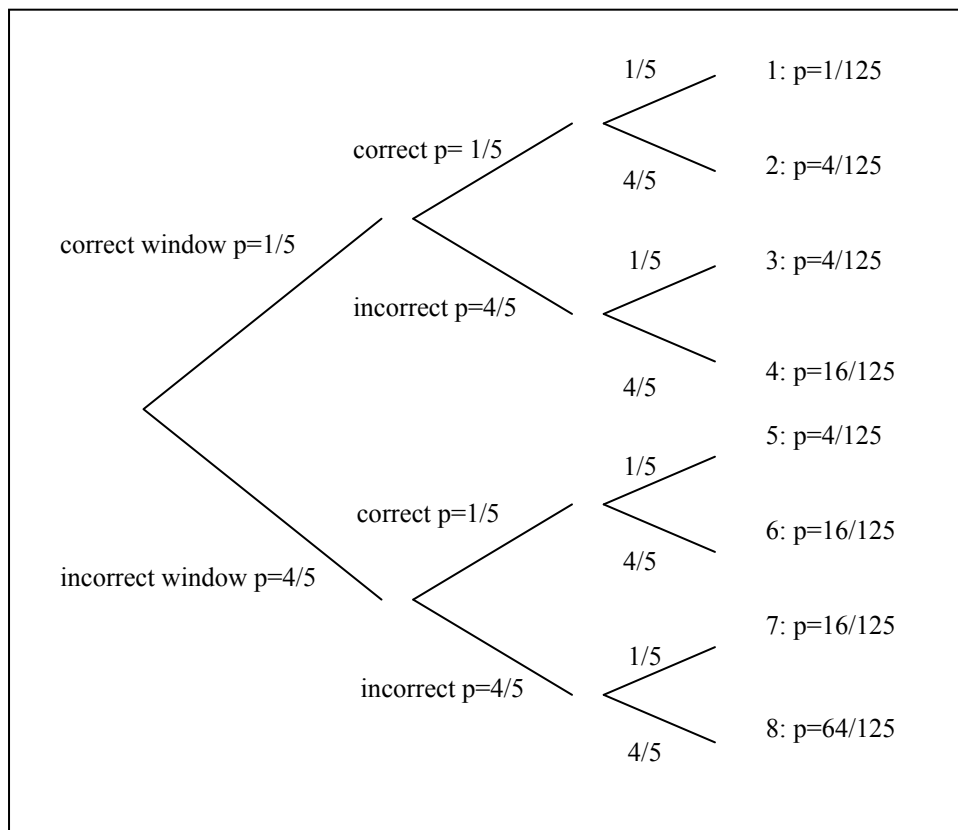


**Figure 1: Probability tree for cones game**

Each child participates on four trials. If the order of trials is ambiguous, unambiguous, ambiguous, unambiguous then your chance of being correct on an ambiguous trial, is  $1/2 \times 1/2 \times 1/2 \times 1/2 = 1/16$ . The probability is not affected by the counterbalancing of the trial order so your chance of being correct on an unambiguous trial, then ambiguous then unambiguous, then ambiguous is also  $1/2 \times 1/2 \times 1/2 \times 1/2 = 1/16$ .

To calculate the probability of answering 3 of 4 trials correctly (the adjusted measure) imagine once again that the order of trials is ambiguous, unambiguous, ambiguous, unambiguous. Variations of the correct adjusted strategy are represented on lines: 2 (Look, Look, Look, Move), 5 (LMLL), 6 (LMLM), 8 (LMMM) and 14 (MMLM). So for any one order of trials the probability of answering 3 of 4 trials correctly (the adjusted strategy) is  $5/16$ .

## 2 Stop Procedure



**Figure 2 : Probabilty tree for stop game**

The probability of stamping on all three correct windows by chance is shown on line 1,  $1/16$ . The probability of stamping on any two (or more) windows is represented on lines 1, 2, 3 and 5 ( $1/125 + 4/125 + 4/125 + 4/125$ ) and is  $13/125$ .



## Appendix B: Stories used in Experiment 4

### 1 Story A

This is John, he's in the kitchen when mum says to him, "Can you take granny's book upstairs to her. It's on the table [ambiguous trial]/It's green [informative trial]."

Look there are three books on the table, a red one, a blue one and a green one.

*prospective trials:* Let's think. There are four things John could do, and there are pictures on these cards. He could take the red book, he could take the blue book, he could take the green book or he could ask mum something else about the book. What should he do? [prompt: "Can you choose a picture?" if child does not spontaneously pick one picture]

(Story continues according to child's strategy.)

If child chooses ask mum then s/he is told "It's the green book"

John takes the green/red book all the way upstairs to granny. When he gets there, he gives granny the book.

(correct strategy) granny says, "That's my book, thank you for bringing it to me."

(incorrect strategy) granny says, "That's not my book." So John's brought the wrong book upstairs and he has to go back downstairs and bring her the right book.

*retrospective trials:* John takes the red book all the way upstairs to granny. When he gets there, he gives granny the book.

Granny says "That's not my book." So John's brought the wrong book upstairs and he has to go back downstairs and bring her the right book.

Let's think about the story. When mum asked John to take the book upstairs there were four things he could have done:

He could have taken the red book, he could taken the blue book, he could taken the green book or he could have asked mum something else about the book. What should he have done? [Can you choose a picture.]

## 2 Story B

This is Jenny. She's at school at the teacher says to her "Jenny, could you give this hat to the girl with the brown hair [ambiguous trial]/to the girl called Emma [informative trial]"

Look there are three girls with brown hair. This one is called Emma, this one is called Kate and this one is Mel.

*prospective trials:* Let's think. There are four things Jenny could do. She could give the hat to Emma, she could give the hat to Kate, she could give the hat to Mel or she could ask the teacher something else about the girl. What should she do? [Can you choose a picture.]

(Story continues according to child's strategy.)

If child chooses ask teacher then s/he is told "Please give it to Emma."

Jenny takes tha hat and goes to give it to Emma/Kate.

(correct strategy) Emma says, "That's my hat, thank you"

(incorrect strategy) Mel says, "That's not my hat" So Jenny's given the hat to the wrong girl.

She needs to take it back and give it to the right girl.

*retrospective trials:* Jenny takes the hat and goes to give it to Mel.

Mel says "That's not my hat." So Jenny's given the hat to the wrong girl.

Let's think about the story. When the teacher asked Jenny to give the hat to the girl with brown hair there were four things she could have done:

She could have given the hat to Emma, she could have given the hat to Kate, she could have given the hat to Mel or she could have asked the teacher something else about the girl. What should she have done? [Can you choose a picture.]

### 3 Story C

This is Sadie. She's gone to the shops to buy some sweets. This is the shopkeeper, here. The shopkeeper is holding a purse. One of the other customer's has left it behind. The shopkeeper says to Sadie "Can you give this purse to the lady wearing the hat? [ambiguous trial]/ the hat with the flower on? [informative trial]"

Look there are three ladies there, wearing hats. One has a bobble hat, one has a feather in her hat and one has a flower in her hat.

*prospective trials:* Let's think. There are four things Sadie can do. She can give the purse to the lady with the bobble hat, she can give the purse to the lady with the feather in her hat, she can give the purse to the lady with the flower in her hat, or she could ask the shopkeeper something else about the lady's hat. What should she do? [Can you choose a picture?]

(Story continues according to child's strategy.)

If child chooses ask the shopkeeper s/he is told "The lady with the flower in her hat"

Sadie takes the purse and gives it to the lady with the flower in her hat/ the lady with the feather in her hat.

[correct strategy]: The lady with the flower in her hat says "That's my purse, thank you very much."

[incorrect strategy]: The lady with the feather in her hat says “Oh, that’s not my purse.” So Sadie has given the purse to the wrong lady.

*retrospective trials*: Sadie takes the purse and gives it to the lady with the feather in her hat. The lady says “Oh, that’s not my purse.” So Sadie has given the purse to the wrong lady. Let’s think about the story. When the shopkeeper asked Sadie to give the purse to the lady wearing the hat there were four things she could have done: she could have given it to the lady with the bobble hat, she could have given it to the lady with the flower in her hat, she could have given it to the lady with the feather in her hat, or she could have asked the shopkeeper something else about the lady’s hat. What should she have done? [Can you choose a picture?]

#### 4 Story D

There’s a visitor in school, here she is. She’s going to go home and she says to Brian “Can you bring me my bag, it’s hanging on the peg. [ambiguous trial]/ it’s spotty [informative trials]”

Look there are three bags hanging up. One is spotty, one is stripy and one has stars on it.

*Prospective trials*: Let’s think. There are four things Brian can do. He can bring the visitor the spotty bag, he can bring her the stripy bag, he can bring her the bag with stars on or he can ask her something else about the bag. What should he do? [Can you choose a picture] (Story continues according to child’s strategy.)

If child chooses ask visitor s/he is told “It’s spotty.”

Brian takes the spotty/stripy bag and gives it to the visitor.

(correct strategy) She says “That’s my bag, thank you very much”

(incorrect strategy) She says “That’s not my bag” So Brian’s brought the wrong bag and he’ll have to go back and get the right one.

*retrospective trials*: Brian takes the stripy bag and gives it to the visitor.

She says “That’s not my bag” So Brian has brought the visitor the wrong bag.

Let’s think about the story. When the visitor asked Brian to bring her her bag, there were four things he could have done, there are pictures on these cards:

He could have brought her the spotty bag, he could have brought her the stripy bag, he could have brought her the bag with stars on or he could have asked her something else about the bag. What should he have done? [Can you choose a picture].

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