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ABSTRACT

This study examines the ability of 20 5- and 6-year-old children to determine whether an inference could reliably be made or whether a problem was undecidable. Children were given a random series of 8 decidable and 16 undecidable problems in which they had to determine in which of 2 houses a target character could be found. There were two characters of different sizes (a giant and a dwarf) and a series of four two-dimensional houses of decreasing size. Children of both ages were successful at dealing with the decidable problems. There were no age differences in performance. Children asked for extra information more often when problems were undecidable than when they were decidable. Examination of responses to undecidable problems suggested that the more similar the appearance of the pair of houses, the easier it was to detect the problem as undecidable. Children as young as 5 years may be aware that while certain problems are undecidable and can be resolved with extra information, others remain unresolvable. Awareness of the necessity of logical reasoning appears to develop very early, and its origins may be found in the preschool years. (Author/RJC)

REASONING BY YOUNG CHILDREN: KNOWING WHEN AND WHEN NOT TO MAKE AN INFERENCE

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Running Head: Reasoning by young children

ABSTRACT

An experiment is reported which examines the ability of 5- and 6-year-old children to determine whether an inference may reliably be made or whether a problem is undecidable. Children were given a random series of decidable and undecidable problems in which they had to determine in which of two houses a target character could be found. There were no age differences in performance, and children asked for extra information more often when problems were undecidable. Some types of undecidable problem proved easier to detect than others, and children as young as 5 years may be aware that while certain problems are undecidable and can be resolved with extra information, others remain unresolvable. Awareness of the necessity of logical reasoning appears to develop very early, and its origins may be found in the preschool years.

REASONING BY YOUNG CHILDREN: KNOWING WHEN AND WHEN NOT TO MAKE AN INFERENCE

Recent research has shown that children as young as 2 or 3 years do show some reasoning ability. They can make transitive inferences (Bryant & Trabasso, 1971; Bryant, 1974); behavioural inferences (Hewson, 1978; Crisafi & Brown, 1986), and can determine the truth of a conclusion based on a pair of initial premises (Hawkins, Pea, Glick, & Scribner, 1984; Dias & Harris, 1988). However, there appear to be limits to young children's abilities and often they fail to appreciate the logical necessity of their reasoning. This has been demonstrated with problems for which there are several possible outcomes instead of just a single, necessary solution.

In one study, Pieraut-Le Bonniec (1980) showed children a box with two holes of different sizes in the top. There were two drawers, one below each of the holes. A ball could only pass through the larger hole, but a narrow stick could pass through either of the holes. With the box hidden behind a screen, children were told the size of one the holes and asked if they knew for certain which object would be in the drawer underneath. Only with the smaller hole can you know for certain because there is a single solution (the stick). With the larger hole there are two possible solutions and it is not possible to infer which object will be in the drawer without additional information. Young children were unable to distinguish these two types of problem and typically made a premature inference on the undecidable problem, thus demonstrating "premature closure" (Lunzer, 1973). It was only at 10 years that children began to state that you must open the drawer to solve the undecidable dual-solution problem.

Other research has also found that young children are generally unable to distinguish between decidable and undecidable problems, and they appear unaware of the circumstances in which their reasoning is merely consistent with the premises but is not necessarily true (Somerville, Hadkinson, & Greenberg, 1979; Scholnick & Wing, 1988; Horobin & Acredolo, 1989). However, there is disagreement about the age at which such understanding first appears. Somerville et al. (1979) found that both 5- and 6-year-old children could reason efficiently on decidable problems, but only 6-year-olds could identify problems which were undecidable and for which extra information was required. Studies by Wollman, Eylon, and Lawson (1979); Acredolo and Horobin (1987), and Scholnick and Wing (1988) suggest that detection of undecidable problems appears somewhat later between 7 and 8 years.

These observations of Somerville et al. (1979) suggest that an important change in reasoning ability may occur between 5 and 6 years, and 6 years remains the earliest reported age for children's appreciation of logical necessity. We therefore decided to re-examine this finding with a different task in order to obtain converging evidence for such an early improvement in reasoning. The task we adopted was a modification of a "fantasy" game used by Scholnick and Wing (1988).

There were 10 children aged 5 years (mean = 5:5) and 10 children aged 6 years (mean = 6:5). Each child was first introduced to the main features of the task. There were two characters differing in size (a giant and a dwarf) and a series of four 2-dimensional houses of decreasing size. The houses were constructed from coloured card and were hinged at the top so they could be lifted up to reveal the occupant. The giant could fit inside two of the houses, and the dwarf inside three of them. Children were allowed to play with examples of each house and the two figures to discover which character fitted into which houses. A pretest was then given to ensure that the child understood these relations. Children who failed any questions on the pretest were allowed further time to explore the m-terials.

Chilc·en were told that they would be shown a pair of houses and had to decide where one of the characters (either the giant or dwarf) was living. It was explained that the giant and dwarf kept changing their houses so frequently that even the postman could not always tell where they lived. If the child was uncertain, then he or she could ask a friendly witch who sometimes knew where they could be found. This third character, represented by a small model, would then indicate the correct house by reference to its colour. Pairs of houses were of different colours and could easily be distinguished. The option of asking the witch for information served to counter any reluctance or the part of children to offer a "don't know" response. As an incentive to be accurate, children were supplied with a box of counters and told that if they found the character (either by a direct search or after asking the witch), they would receive an extra counter, but if they made a mistake they would lose a counter. Counters could be traded for sweets at the end of the session.

Each child was given 24 problems of which 8 were decidable and 16 were undecidable. In decidable problems the target character could fit in only one of the houses, while in undecidable problems, the character could fit in either of the two houses. Half of each type of problem involved a giant and half involved a dwarf. Position of the character was varied randomly between left and right positions, and sizes of houses differed across problems. For the undecidable problems, the witch supplied the colour of the correct house on half of the trials and answered "I don't know" on the remaining half. The reason for varying the response of the witch was to discourage use of a "play-safe" strategy in which children might have opted to ask for information on every trial, regardless of whether the problem was decidable or not. Pilot testing had confirmed that children readily learned these rules and could follow the instructions.

Children of both ages were very successful at dealing with the decidable problems. For 5-year-olds, 80% of decidable problems were correctly solved with a direct search; for 6-year-olds, the figure was 90%, but the difference was not significant. Children were also successful at detecting undecidable problems. The proportion of problems on which they asked the witch for information was examined with a 2-way ANOVA with one between factor (age) and one within factor (problem type). Children at both ages asked for information significantly more often on undecidable problems, $F(1,18)=19.6$, $p<.001$, (5 years: decidable mean = 12.5%, undecidable mean = 43.8%; 6 years: decidable mean = 5.0%, undecidable mean = 40.7%). There was no significant effect for either age or the age x problem-type interaction.

Examination of responses to undecidable problems suggested that the more similar the appearance of the pair of houses, the easier it was to detect the problem as undecidable. There were 4 problems in which the two houses were the same size but their colour differed, and 10 problems in which both sizes and colour differed. Children at both ages were more likely to ask for information when only the colour differed (5 years = 70.0%; 6 years = 77.5%) than they were when both size and colour differed (5 years = 28.0%; 6 years = 30.0%), $F(1,18)=26.10$, $p<.001$. The difference in percentage scores between ages was not significant.

After completing these analyses it was discovered that an error had been made in the construction of two undecidable problems. For these problems only, the pairs of houses were in fact identical (same size and same colour). On the hypothesis that detection of undecidability is related to degree of similarity of the houses, it might be supposed that these two problems would produce a high percentage of trials on which children asked the witch for information. However, results showed that the actual level of asking on these problems was significantly lower than for the same-size/different-colour problems (5 year mean = 30.0%; 6 year mean = 25.0%) both for 5-year-olds, Wilcoxon T=1.5, n=8, p<.02 (2-tailed), and for 6-year-olds, T=0, n=9, p<.002 (2-tailed). Percentage scores for the same-size/same-colour and different-size/different-colour problems did not differ significantly at either age.

Despite the fact that some undecideable problems were more difficult to detect than others, children did ask for help more often for each type of undecideable problem than they did for the decideable problems (see Table 1). With scores from both age groups combined, 2-tailed Wilcoxon tests showed that children asked for help on a significantly greater proportion of trials for undecideable, same-size/same-colour problems, T=1.5, n=9, p<.05; undecideable, different-size/same-colour problems, T=0, n=20, p<.002; and undecideable, different-size/different-colour problems, T=0, n=16, p<.002.

These results confirmed that both 5- and 6-year-olds made inferences with a level of accuracy matching that reported by Somerville at al. (1979). However, unlike the finding of Somerville et al., 5-year-olds were as competent as 6-year-olds in their ability to detect undecidable problems and ask for further information. Some undecidable problems were easier to detect than others, and perceptual similarity on a relevant dimension (in this case size) might alert children to the ambiguity of the problem.

There are several reasons why this might occur. It is possible that children learn quite early that a choice between similar items is more uncertain. For example, children as young as 30 months who search in the wrong place for a hidden object frequently choose a location which is similar to the correct one (DeLoache & Brown, 1984). In addition, sensitivity to size constraints also appears to emerge quite early. Smith and Myers (1987) reported a study in which 28-month-olds were allowed to search for either a large or a small toy which had been hidden behind a screen under one of two containers. One container was large and the other was small, and first trial performance revealed a significantly greater than chance choice of the large container when searching for the large object. In contrast, choice of container was divided fairly evenly when the target object was small. This finding parallels the performance of children in the present study and suggests that very young children are aware of situations in which the possible location of some objects can be less certain than the location of others.

Alternatively, it could be that problems in which the houses are the same size impose less of a cognitive load. Having decided that the target character could fit inside house A, the child need only notice that house B is the same size to make the inference that the character could fit in there as well. On problems in which the houses differ in size, the child must first check out house A, remember the outcome, and then proceed to check out house B. Any lapse of memory or reluctance to check out more than one house for size would lessen the chance of detecting such an undecidable problem.

The finding that children were more reluctant to ask for extra information on the two problems in which the houses were identical appears to conflict with the proposal that perceptual similarity assists the child to detect undecideable problems. However, it is possible that children realised there was no point in asking for any information because the witch would be unable to provide any help. The houses were the same colour, and because the witch only gave information about colour there was nothing else she could add. Several children made comments on these problems such as, "I'll have to guess", which suggested they were aware of the difficulty. If this interpretation is correct, then it is possible that in some circumstances young children can determine both that a problem is undecidable and that it is unresolvable. Previous research by Scholnick and Wing (1988) has suggested that recognition of unresolvability is difficult for 8-year-olds, and first appears reliably at around 11 years. Clearly, further work is needed to explore this important issue and to examine the development of understanding of logical necessity during the preschool years. The tasks described in this study offer one method for studying the development of reasoning across this period, and a second study is currently in progress to investigate the early detection of unresolvability.

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Table 1: Percentage of trials for decideable and undecideable problems on which 5- and 6-year-olds asked for help.

	Age	
	5 years	6 years
Decideable	12.5	5.0
Undecidable		
Same size/same colour	30.0	25.0
Same size/diff. colour	70.0	77.5
Diff. size/diff. colour	28.0	30.0
Mean	43.8	40.7