Making Implicit Assumptions Explicit in Verbal Insight Problem Solving

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Abstract

Stereotypical assumptions made during insight problem solving can trigger an initial representation that constrains problem solving (Ohlsson, 1992). Two experiments were conducted to investigate the effect of such assumptions on solution rates and hypothesis generation using verbal insight problems, which have received little attention in the literature. Concurrent verbal protocols were collected in both experiments. In Experiment 1, twelve participants attempted two verbal insight problems: the Unseen Walker and Bombs Away. Solution rates for both problems were poor. Qualitative analysis of verbalizations revealed that participants generated incorrect hypotheses on the basis of an incorrect stereotypical assumption. Experiment 2 aimed to improve performance on the same verbal insight problems through generic training to identify inconsistencies between the problem solver's representation and the problem specification. After training, twelve participants completed the test problems (T condition) and another twelve were permitted to use an aide memoire in order to reduce cognitive load (TA condition: Pfeiffer, 2004). Experiment 1 served as a no training (NT) control condition. Training improved solution rates although the pattern of results varied between problems, such that the aide memoire was more beneficial for the Bombs Away problem. Results supported the notion that stereotypical assumptions can inhibit solution of verbal insight problems and that fine-grained training involving inconsistency checking between the problem statement and a person's interpretation of it has some benefit at overcoming these barriers.

Introduction

There are different theoretical explanations concerning how insight is achieved (Ohlsson, 1992; Knoblich, Ohlsson, & Raney, 2001; MacGregor, Ormerod, & Chronicle, 2001). According to Ohlsson (1992), insight problems trigger an initial representation that reduces the likelihood of generating the relevant knowledge required to solve a given problem. Insight problems can be categorized as visuo-spatial problems (e.g., matchstick arithmetic, Knoblich et al., 2001; and nine-dot problem, MacGregor et al., 2001) or verbal problems (e.g., pound coins problem, and reading in the dark problem, Dominowski, 1994). Lateral thinking problems (DeBono, 1967) are a type of verbal insight problem that has received little attention within the problem solving literature. An example of a lateral thinking problem is the Unseen Walker problem:

> On a busy Friday afternoon, a man walked several miles across London from Westminster to Knightsbridge without seeing anybody or being seen by anybody. The day was clear and bright. He had perfect eyesight and he looked where he was going. He did not travel by any method of transport other than by foot. London was thronged with people yet not one of them saw him. How? (Sloane, 1992, p. 11)

People find this problem difficult because the stereotypical assumption that the man is walking above ground constrains the solution path. Consistent with Ohlsson's (1992) definition, the initial representation of the man walking above ground constrains the problem solver from thinking of the solution that the man is walking underground. However most of the research on insight problem solving has investigated visuo-spatial rather than verbal problems. Therefore the aims of this paper are to investigate the role of implicit assumptions underlying verbal insight or lateral thinking problems and how problem solving performance can be facilitated through training that makes implicit assumptions explicit.

The comprehension of text requires the reader to elaborate the information provided by making inferences or assumptions (Lea, 1995). During lateral thinking, the problem solver makes an inappropriate assumption or inference from words and sentences using their past knowledge and experience although this inference may be both automatic and implicit. In any situation, a person brings to bear their own knowledge and experience. In cognitively underspecified situations, as in lateral thinking, there is a bias to select the most frequent response (Reason, 1990). William James (1890) was the first to recognize the negative effect that habit could have on performance. This bias is also consistent with the availability heuristic (Kahneman, Slovic, & Tversky, 1982). Ohlsson's (1992) Representational Change Theory proposes that past experience triggers an incorrect initial representation, which results in an impasse, a mental state in which problem solving activity ceases. Insight occurs when an impasse is broken by changing that representation. Representations concerning the goal state are changed via a mechanism called 'constraint relaxation' (Ohlsson, 1992).

The earliest study to attempt to ameliorate the role of assumptions in insight problem solving was reported by Wicker, Weinstein, Yelich, and Brooks (1978). They provided generic training to facilitate performance on verbal insight problems involving different assumptions. As part of training, participants were informed that unnecessary assumptions affect how problems are viewed and they were given practice in using a reformulation strategy to avoid them. This strategy encouraged participants to continuously re-interpret a problem after assessing their assumptions about the problem. Participants were given feedback during

training in terms of the problem solution and then were tested on eleven problems. (A list of the problems was not provided by Wicker et al., 1978). Solution rate was raised to 63% (Experiment 2). A possible reason why the solution rate was not higher is that participants were not actually trained in the process of how to identify assumptions in problem solving. Furthermore, as verbal protocol was not collected, it was not known to what extent participants had applied the reformulation strategy to solve test problems.

To date, studies by Ansburg and Dominowski (2000) and Dow and Mayer (2004) have also investigated the effects of training on verbal insight problems. The training used by Ansburg and Dominowski (2000, Experiment 1) emphasized changing the representation of a problem in a similar manner to Wicker et al. (1978). However, Dow and Mayer (2004) trained participants in different types of insight problems including verbal ones. Training on verbal insight problems entailed instructing participants to look for a 'play on words' in problems and then to define and analyze what the word meant in terms of the problem context. Only solutions to spatial problems were improved.

In an attempt to understand further the cognitive processes used during lateral thinking problems, verbal protocol methodology was employed in the following two experiments. The use of verbal protocols has been the subject of much discussion. Schooler, Ohlsson, and Brooks (1993) argued that verbalizations adversely affect insight problem solving, which they termed verbal overshadowing. However, Ericsson and Simon (1993) carefully specified the conditions in which such protocols are valid, and suggested the need for adequate instructions and practice in thinking aloud, which were criticisms of Schooler et al.'s study made by Fleck and Weisberg (2004). Following Erricson and Simon's (1993) suggestions, Fleck and Weisberg (2004) found no evidence of verbal overshadowing on insight problem solving when results were compared to a silent control group.

Experiment 1

The aims of Experiment 1 were to, first, verify the nature of any stereotypical assumptions that may block problem solving and, second, to examine their effects on hypothesis generation. Of particular interest was the role of implicit assumptions or inferences that people make, which result in an impasse that constrains subsequent problem solving (Ohlsson, 1992). Data from this experiment will provide information regarding the generalizability of such difficulties. It will also guide the nature of training that is designed to overcome these difficulties in Experiment 2.

Method

Participants Twelve non-psychology students from Cardiff University took part in Experiment 1 and their ages ranged from 18 to 23 years.

Materials All participants attempted to solve two test problems. All materials were presented in black, size 11/12 font type on white A4 paper. The problems were taken with permission, from Sloane (1992). Participants' verbalizations during problem solving were recorded using a cassette player, and a stopwatch was utilized to time their responses.

Test problems Each test problem was selected because it was hypothesized to involve a constraint that could block participants from reaching the correct answer.

Problem 1: UNSEEN WALKER

> On a busy Friday afternoon, a man walked several miles across London from Westminster to Knightsbridge without seeing anybody or being seen by anybody. The day was clear and bright. He had perfect eyesight and he looked where he was going. He did not travel by any method of transport other than by foot. London was thronged with people yet not one of them saw him. How? (Sloane, 1992, p. 11)

Hypothesized constraint: The man was walking above ground along the streets.
Correct answer: The man was walking underground through the sewers.

Problem 2: BOMBS AWAY

> One night during the Second World War, an allied bomber was on a mission over Germany. The plane was in perfect condition and everything on it worked properly. When it had reached its target, the pilot ordered the bomb doors to be opened. They opened. He then ordered the bombs to be released. They were released. But the bombs did not fall from the plane. Why should this be so? (Sloane, 1992, p. 8)

Hypothesized constraint: The plane was flying the right way up.
Correct solution: The plane was flying upside-down.

Design The order of presentation of the two problems was counterbalanced. The main dependent variables were whether the participants solved the test problems and whether the participants broke the constraint in the problems but did not reach the correct solution.

Procedure Participants completed the study individually in a quiet room. Each participant was given an introduction to the study and was then requested to 'think aloud' during each problem. To facilitate this, participants were given practice exercises involving different tasks and contexts as recommended by Ericsson and Simon (1993). These involved solving a multiplication problem, calculating the number of windows in the participant's house, and naming twenty animals. After these practice tasks, participants then completed each of the two test problems. Participants were able to refer to the problems during attempted solution and were given a five-minute time limit for each. If participants were silent for a period of time, the experimenter used two non-directive prompts to maintain their verbalizations. These were: 'What are you thinking?' and 'Please keep talking'. Participants' responses were recorded continuously

for this time. If the participant solved the problem in less than five minutes then recording ceased and they were informed that they had reached the correct solution.

Results and Discussion

In general, problem solving was poor. Solution rate was 8% for the Bombs Away and 42% for the Unseen Walker. The solution rates corresponded exactly with the frequency of broken constraints for each problem, indicating that if a participant broke the constraint, then they successfully solved the problem.

Verbal protocols were examined in order to shed light on the strength and effect of the hypothesized constraint for each problem. In order to accomplish this, the number and nature of incorrect hypotheses were identified. There was a considerable number of incorrect (and different in parentheses) hypotheses generated by the twelve participants. For the Unseen Walker and Bombs Away, there were 33 (20) and 42 (27) hypotheses, respectively. A significant measure of the strength of the problem constraints is the frequency and percentage of incorrect hypotheses generated that failed to break the problem constraints. This was 33 (100%) and 42 (100%) for the Unseen Walker and Bombs Away, respectively. Some hypotheses explicitly described the problem constraint. For example, hypotheses for the Unseen Walker included 'man walked along back alleys' and 'man walked through a building'. For Bombs Away, the hypothesis that 'the plane is too low' is consistent with the problem constraint that the plane is flying the right way up. Given the number and nature of incorrect hypotheses generated, it is reasonable to assume that the stereotypical assumptions associated with each problem were implicit and formed a strong psychological barrier to problem solution, particularly for Bombs Away.

To provide further clues on how to develop training, incorrect hypotheses were categorized as either inconsistent or incomplete with respect to the problem specification. Inconsistent hypotheses were so called because they contradicted some information given in the problem specification whereas other incorrect hypotheses were consistent but incomplete because they failed to account for some detail in this specification. Thus, for example, in 'Bombs Away' the hypothesis that 'no bombs were onboard the plane' is inconsistent because it is contradicted by the fact that 'they were released', as given in the problem specification. Strictly there was no significant difference between problems in the number of inconsistent hypotheses generated, $F(1, 11) = 4.44$, $p = 0.06$, $MSE = 7.04$ (Table 1) although there were approximately twice as many generated for Bombs Away. In total, the inconsistent hypotheses proposed for the Unseen Walker and Bombs Away represented 37% and 62% respectively, of the total number of incorrect hypotheses for each problem.

There was no significant difference between problems in the number of consistent but incomplete hypotheses generated, $F(1, 11) = 0.42$, $p > 0.05$., $MSE = 1.04$ (Table 1). In total, incomplete hypotheses for the Unseen Walker and Bombs Away, respectively, represented 60% and 38% of the total number of incorrect hypotheses for each problem.

Table 1: Frequency of different types of incorrect hypothesis

		Problem	
Hypotheses		Unseen Walker	Bombs Away
Inconsistent with problem specification			
	Mean	1.08	2.17
	SD	1.44	1.03
Consistent but incomplete with problem specification			
	Mean	1.75	1.33
	SD	1.54	1.07

The technical and unfamiliar nature of the Bombs Away problem may explain why a high percentage of inconsistent hypotheses were generated for this problem and not the Unseen Walker. However, as the context of the Unseen Walker was more familiar, participants were able to generate hypotheses that were consistent with the problem specification yet incomplete explanations of all the details in the problem.

Experiment 2

Experiment 1 demonstrated that a stereotypical assumption or inference made during problem solving can have a strong effect on hypothesis generation. These assumptions produce strong impasses that often cannot be broken spontaneously. The aim of Experiment 2 was to provide generic training, similar to Wicker et al. (1978), to facilitate performance on a range of novel verbal insight problems.

The first stage of the training entailed alerting trainees to the role of incorrect stereotypical assumptions and how they can inhibit problem solving. The second stage provided training in a strategy designed to overcome such assumptions. The approach to training adopted in this experiment was similar to that of Patrick, Grainger, Gregov, Halliday, Handley, James, and O'Reilly (1999) and focused on identifying any inconsistencies between a person's interpretation of a problem and the problem specification. It is predicted that this comparison may draw trainees' attention to their implicit assumptions, and thus facilitate changes in representation. In order to develop and capitalize on such a cognitive process, the training literature considers it essential that practice with feedback is provided (e.g., Newell & Rosenbloom, 1981; Anderson, 1983; Goldstein, 1986). Therefore, the training will entail practice in identifying inconsistencies between assumptions and the problem specification. However, because this may impose extra cognitive load on working memory (Pfeiffer, 2004), an aide memoire is provided in one training condition so that

participants are able to write down their interpretations during problem solving.

Method

Participants Twenty-four non-psychology students from Cardiff University took part in Experiment 2 and their ages ranged from 18 to 23 years. They were randomly allocated to one of two training conditions.

Materials Materials used were the same as in Experiment 1. However, in one training condition (TA), participants were also provided with an aide memoire during problem solving i.e., a pen and paper.

Training programme All participants took part in a brief training programme (T) that had the following two main objectives:-

1. To make participants' aware that an incorrect interpretation (or representation) of a problem may block the correct solution.
2. To provide practice at identifying and overcoming inconsistent interpretations.

For the awareness training, participants read through two examples to illustrate how blocking effects operate. For example:

> 'Why are 1988 pennies worth more than 1983 pennies?' (Sloane, 1992, p. 28). In this problem people might assume that the numbers refer to years, which would then block the correct interpretation that the numbers refer to quantities of pennies. Therefore, 1998 pennies would be worth £19.88, which is more than £19.83.'

The second part of the training involved four stages that focused on overcoming such blocking effects by providing increasingly independent practice. In the first stage, participants were presented with two different problems, each having two written interpretations that were inconsistent with the problem specification. Participants were required to identify these inconsistencies and, if they failed to do so, were prompted by the experimenter. An example of one problem was:

> 'Archie and Ben were professional golfers and keen rivals. One day during a game, they had each scored 30 when Ben hit a bad shot. Archie immediately added 10 to his own score. Archie then hit a good shot and he had won the game. Why? (Sloane, 1992, p. 21)

Possible interpretation: 'Two friends were playing golf, they were both on 30 points, then one reached 40 points and won.'

The interpretation is inconsistent with the problem specification because it does not state that Archie and Ben were friends, nor that they were playing golf. The solution was that they were playing tennis.

The second stage of training involved participants reading another similar problem, writing their own interpretation, and then attempting to identify any inconsistencies between their interpretation and the actual problem specification. After this participants attempted to solve the problem. The experimenter prompted the participants who were unable to complete any aspects of this.

Support given during the training was reduced gradually (Welford, 1968) in order to prepare participants for problem solving in the test condition. Hence, in the third stage of this training, participants were required to solve a standard problem without writing their own interpretation but being prompted, if necessary, by the experimenter. In the fourth and final stage, participants attempted to solve a problem without the experimenter prompting although feedback was given at the end.

Test problems The same two problems were used as in Experiment 1.

Design The effects of training (T) and training with an aide memoire during testing (TA) were evaluated against the control condition (NT) from Experiment 1. As with Experiment 1, the presentation order of the problems was counterbalanced.

Procedure The procedure was similar to that of Experiment 1. After completing the 'think aloud' training, both T and TA conditions completed the training programme, followed by the test problems whilst thinking aloud. However, participants in TA were permitted to write down their interpretations of each test problem during testing.

Results and Discussion

As in Experiment 1, participants in Experiment 2 correctly solved the problems once they had broken the problem constraint.

Given the nature of the frequency data, Fisher's Exact tests were carried out to test solution rates between the training conditions for each problem. For the Unseen Walker, a significant difference was found between NT and T ($p < 0.05$) (Figure 1). This suggests that making the comparison between participants' interpretations and the problem specification was feasible and improved solution rate in the T condition for the Unseen Walker. However the facility of writing down interpretations in TA did not produce any added benefit over NT although there is a non-significant tendency for a higher solution rate in TA. For Bombs Away, significant differences were found between NT and TA, and T and TA (all $ps < 0.05$). Possibly because Bombs Away was perceived, inappropriately, as a more technical problem, participants benefited from writing down their interpretations in TA as this reduced cognitive load, which in turn facilitated better performance than in NT and T (Figure 1). However training without the aide memoire was unable to improve performance presumably due to cognitive load imposed by the nature of the problem.

Again, incorrect hypotheses were identified from the verbal protocols and analysed. One-way analysis of variance revealed significant differences between training conditions in the frequency of incorrect hypotheses for Bombs Away, $F(2, 35) = 12.44$, $p < 0.001$, $MSE = 22.11$ (Table 2). Tukey's

HSD revealed a significant reduction in the frequency of such hypotheses for TA than NT ($p < 0.001$) and T ($p < 0.01$). Hence, the use of the aide memoire to help make comparison between interpretations and the problem statement reduced the number of incorrect hypotheses being generated for this problem. It should be noted that all of these incorrect hypotheses were consistent with an inappropriate representation based on the hypothesised problem constraint. There were no significant differences in the frequency of incorrect hypotheses for the Unseen Walker, $F(2, 35) = 0.93$, $p > 0.05$, $MSE = 6.36$), although the number in the TA condition was less than half the number in the NT condition. The number of hypotheses consistent with the problem constraint was the same as the number of incorrect hypotheses reported for both problems (Table 2).

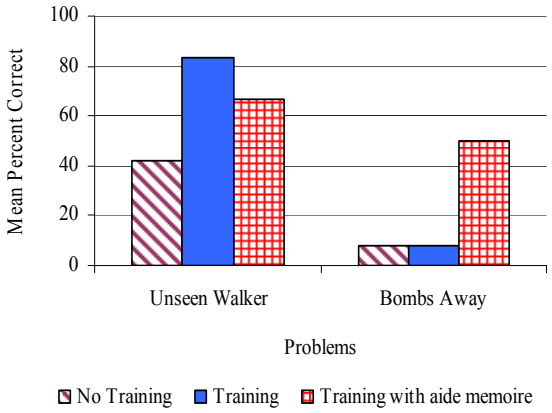

Figure 1: Percentage correct solutions for training conditions and problems

Table 2: The effect of training condition and problem on incorrect hypotheses

	Training Condition		
Problem	NT	T	TA
Unseen Walker	33	29	16
Bombs Away	42	38	12

Two-way (training x problem) analyses of variance were conducted to identify any effects on the number of inconsistent, and consistent but incomplete hypotheses with the problem statement generated by participants. No significant effects of training, $F(1, 33) = 3.16$, $p > 0.05$, $MSE = 4.35$, and problems, $F(1, 33) = 2.77$, $p > 0.05$, $MSE = 4.01$, were found for inconsistent hypotheses for either problem. For incomplete hypotheses, training condition was significant, $F(2, 33) = 5.94$, $p < 0.01$, $MSE = 5.94$, problem was not significant $F(1, 33) = 0.11$, $p > 0.05$, $MSE = 0.22$, and there was no interaction between these factors. Using Tukey's HSD for multiple comparisons, the TA condition was better than NT ($p < 0.01$) and T ($p < 0.05$) (Table 3). Fewer incomplete hypotheses were generated in TA, suggesting that an aide memoire facilitated cognitive processing such that participants were less likely to generate hypotheses that did not fully explain the problem.

Table 3: Frequency of incomplete hypotheses for training conditions

Training Condition	Mean	SD
NT	1.54	1.32
T	1.29	1.83
TA	0.33	0.56

General Discussion

Experiment 1 demonstrated that participants were poor at solving verbal insight problems. Based on the difficulties experienced by participants in Experiment 1, training was developed to overcome these difficulties in Experiment 2. The difficulties related to the incorrect assumptions that participants made concerning each problem. In particular, an incorrect stereotypical assumption resulted in incorrect interpretations that biased the types of hypotheses generated. Due to the unfamiliar context of the Bombs Away problem, participants tended to generate a greater number of incorrect hypotheses that contradicted the problem specification in comparison with the Unseen Walker. In contrast, the context of the Unseen Walker was familiar, and therefore participants were more successful with this problem and generated incorrect hypotheses that were consistent but sometimes incomplete with respect to the problem specification.

The training in Experiment 2 entailed comparing interpretations of the problem with the problem specification in order to try and identify the incorrect assumption. There were differences in solution rates between the training conditions for both problems. An increase over the NT condition in solution rate was found for the Unseen Walker in T, and in TA for Bombs Away. Arguably, Bombs Away was perceived by participants as more of a technical problem, hence the aide memoire in TA helped to reduce cognitive load and also to facilitate more solutions. This result for Bombs Away was further supported by the finding that there was a reduction in the number of incorrect hypotheses that were consistent with the problem constraint that the plane was flying the right way up.

The results support the literature that a bias towards a high frequent response based on a stereotypical assumption can limit hypothesis generation (Reason, 1990). However, consistent with Patrick et al. (1999), the results suggest that inconsistency checking is a useful process in breaking such barriers to solve verbal insight problems. In particular, the training enabled participants to practice the stages of identifying inconsistencies between their interpretations and the problem specification, thus implicit assumptions could sometimes gradually be made explicit and incorrect and inconsistent hypotheses could be inhibited.

Differences in solution rates and the types of hypotheses generated were found for both problems, thus suggesting that participants found the Bombs Away more difficult than the Unseen Walker. These differences may be due to the idiosyncratic nature of the problems. Only two problems were selected for these two experiments due partly to the lengthy procedure involved in the qualitative analysis of the data. This is a limitation of the experiments along with the small sample size of only twelve participants per training condition.

In summary, hypothesis generation in verbal insight problem solving has been overlooked (e.g., Wicker et al., 1978; Ansburg & Dominowski, 2000; Dow & Mayer, 2004). Hence, the think aloud methodology was employed in the experiments reported in this paper and the verbal protocol data enabled analysis of the hypotheses generated for each problem. In particular, it was possible to chart the powerful influence that stereotypical assumptions had on hypothesis generation. A novel feature introduced in Experiment 2 was the development of a fine-grained training regime that was geared to facilitating identification of the implicit assumption that is typically associated with such problem solving through a process of inconsistency checking between the problem statement and a person's interpretation of it. Given the cognitive load that this process may impose, the utility of an aide memoire during problem solving was investigated and was found to be particularly beneficial in solving the Bombs Away problem, possibly due to its apparently technical nature. However further research is needed using a range of verbal insight problems with a larger sample size, in order to draw conclusions regarding the generalizability of these findings and to identify the specific cognitive difficulties associated with different problems that require remediation through training.

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