# Training insight problem solving through focus on barriers and assumptions


## Abstract

Recent research has reported successful training interventions that improve insight problem solving. In some ways this is surprising, because the processes involved in insight solutions are often assumed to be unconscious, whereas the training interventions focus on conscious cognitive strategies. We propose one mechanism that may help to explain this apparent disconnect. Recognition of a barrier to progress during insight problem solving may provide a point of access to the tacit constraining assumptions that have misled the solution process. We tested this proposal in an experiment that examined the effects of different training routines on problem solving. The experiment compared four training routines, focusing either on barriers and assumptions combined, barriers alone, assumptions alone, or goals, with two control conditions. Outcomes were measured using eleven spatial insight problems. The results indicated that training that combined focus on barriers and assumptions was significantly more effective than all other conditions, supporting the proposition that recognizing and reinterpreting barriers may assist in surfacing the unwarranted assumptions that prevent problem solving.

In recent years many public and private organizations have expressed a need to foster creativity and innovation. In the public sector, granting agencies in North America and Europe have introduced programs to fund research in innovation, and all levels of education now recognize the importance of fostering creative thinking. In the private sector, top companies, such as GE and Proctor & Gamble, have explored strategies to increase creativity and imagination in managers and executives, convinced that this is the avenue to continued or greater success. “Practicing creativity and innovation” was the number one choice among 500 CEOs surveyed by the American Management Association, for ways to survive in the 21st Century.

Creative problem solving has been defined as finding non-obvious routes to reach a goal (Brophy, 2006). Insight–commonly associated with the “Aha!” experience– is a particular class of creative problem solving that meets this general definition, but has tended to be studied separately. Some consider insight to be the component of the creative process that underlies important technical and scientific innovations (Schooler & Melcher, 1995; Smith, Ward & Finke,1995; Tardif & Sternberg, 1988). Anecdotal examples of insightful scientific and technical innovations abound, and include the discovery of the Periodic Table, the invention of Velcro, and the development of the Ipod.

Given the potential benefits of promoting insightful problem solving, it is not surprising that it has been the focus of popular forms of creativity training (de Bono, 1971, 1985, 1992). However, early reports in the academic literature on the effects of instruction and training were mixed. Maier (1933), for example, provided 20 minutes of instruction, including examples and hints, and found that performance on a spatial insight problem was slightly superior to that of a control group. However, a subsequent study using similar instructions on the same spatial problem failed to find any positive effects over a number of experiments (Duncan, 1961). The recent general resurgence of interest in insight ( ) has rekindled research into insight training, often with seemingly beneficial results (Ahmed & Patrick, 2006; Ansburg & Dominowski, 2000; Chrysikou, 2006; Cunningham & MacGregor, 2008; Dow & Mayer, 2004; Wicker, Weinstein, Yelich, & Brooks, 1978). Ansburg and Dominowski (2000), for example, reported five experiments testing the effects either of training and brief instructions on performance on a set of 15 verbal insight problems. In all five experiments, participants in training/instructional conditions significantly out-performed those in control conditions. Ansburg and Dominowski concluded that insightful problem solving can "…be conceptualized as a trainable, general thinking skill…" (p.48). Similarly, other researchers have reported positive effects of brief training procedures aimed at relaxing implicit constraints or recognizing and overcoming tacit assumptions (Ahmed and Patrick, 2006; Cunningham & MacGregor, 2008; Dow & Mayer, 2004; Wicker, Weinstein, Yelich, & Brooks, 1978).

In some respects, it appears surprising that insight problem solving would be responsive to training. One of the dominant views is that insight involves representational changes that take place unconsciously (Knoblich, Ohlsson, Haider, & Rhenius, 1999), and it seems unlikely that the unconscious processes of the type envisaged would be amenable to brief instructional interventions. As Ohlsson (1992) has stated, the impasse that must be broken for insight to occur is not "…something that can be cured by the use of particular problem-solving strategies, meta-cognitive skills or the like…" (p.22). The implicit, incorrect, assumptions that result in impasse would seem, from their very nature, not to be open to cognitive manipulation. In the present article we propose an additional mechanism that may be involved, that could provide a conscious access point to changing implicit assumptions.

*Assumptions and barriers*

To introduce the proposal, we begin with an informal description of problem solving behaviors that we have observed previously during experimental sessions. For purposes of illustration, we describe the behaviors in the context of one of the eleven insight problems used in the present study. We devised the problem as an analog to one of Mendeleev's insights in the process of discovering the Periodic Table of the elements. An avid solitaire player, Mendeleev approached the task by arranging cards representing the known elements in rows and columns ordered by increasing atomic weights. However, a repeating pattern only emerged if he left gaps in the table, which he suggested would be filled by as yet undiscovered elements. To obtain a simplified version involving some of the same principles as Mendeleev's problem, we used the 12 court cards from a standard deck of cards, where the objective is to arrange the 12 cards in a table so that each row and each column contains only one King, one Queen and one Jack. The "trick" is that this can only be achieved by leaving gaps in the table.

Most people do not solve this problem immediately, and about 60% will still be unsuccessful after 5 minutes. The main source of difficulty is suggested by people's comments. Some spontaneously state that "there are too many cards" to be able to solve. Others will express the same idea when asked what is getting in the way of solving. Sometimes there are incorrect but "creative" solution attempts that are a direct response to this perception that there are too many cards, such as hiding one card under another of the same value. In some cases, the person remains focused on the problem of "too many cards" and fails to solve. In other cases, the required breakthrough is made. This occurs when the grid is expanded beyond the initial 3x3 or 3x4 confines, by leaving spaces between cards. This expansion of the space is consistent with a conceptual figure/ground reversal, where attention switches from the cards themselves, and the fact that there are too many, to the space that they occupy, and the fact that it has been too constrained (Cunningham, MacGregor, Gibb & Haar, 2010).

We believe that the foregoing account is a specific example of a more general process that may arise during insight problem solving. During the initial phase of problem solving, the person may become aware of something that he or she sees as an impediment to reaching the goal. This perceived barrier directly results from an initial, unproductive, representation of the problem. In the cards problem, above, we observed people acting as if they assumed that the grid should be complete, with no spaces. The perceived problem of too many cards is a direct consequence of this unwarranted assumption. In this view, the perceived barrier is therefore a *symptom* of the unnoticed or unconscious assumptions that underlie the initial misleading representation. The barrier may therefore provide cues that point to the presence of those assumptions or to alternative problem representations. In doing so, the perceived barrier may give rise to what are, effectively, self-generated hints. Like any other hints, these may not be effective (Chronicle, Ormerod, & MacGregor, 2001; Kokinov, Hadjiilieva, & Yoveva,1997), in which case the person may remain trapped in a "fixation cycle", continuing to focus on the perceived barrier, and repeating variations on the same unproductive solution attempts. However, sometimes the hint may be effective in guiding solution attempts in a new direction. An important point is that, because the conscious barrier is directly related to the tacit assumptions, it may provide a point of leverage for shifting the representation into a more productive form.

From this perspective, and consistent with Fleck and Weisberg's (2004) observation of "top-down" restructuring, insight problem solving can be driven by conscious efforts that have a focus and direction. Thus, in the previous example, restructuring may be brought about by the conscious focus on "too many cards" being re-interpreted as "too little space". If this proposal is correct, then it follows that insight problem solving may be facilitated through an instructional intervention aimed at both assumptions and barriers, and that this should be more effective than instruction aimed at either alone. This is the hypothesis tested below.

*Instructional interventions*

As mentioned previously, a number of studies have reported experimental tests of the effects of training strategies on insight problem solving. Typically, the interventions have involved instruction, followed by practice, followed by test problems (Ahmed & Patrick, 2006; Ansburg & Dominowski, 2000; Cunningham & MacGregor, 2008; Wicker et al., 1978). During the test phase, participants may be given written or verbal reminders about key elements of the instructions and/or their relevance to the test problems (Chrysikou, 2006; Cunningham & MacGregor, 2008; Wicker et al. 1978).

The studies have differed in the theoretical motivation for the design of the instructional interventions. In three cases, instructions were specifically directed at identifying or avoiding implicit assumptions (Ahmed & Patrick, 2006; Cunningham & MacGregor, 2008; Wicker et al., 1978). Such approaches are consistent with the widely-held proposition that constrained or stereotypical thinking leading to inappropriate problem representation is a common component in the “insight sequence” (Isaak & Just, 1996; Ohlsson, 1992). Dow and Mayer (2004) developed three different sets of instructions, one each for spatial, verbal and mathematical insight problems. The goal was to investigate whether insight problem solving depends on domain-specific or domain-general skills. Only the training method designed for spatial problems was effective. Like the previous approaches, it focused on avoiding self-imposed constraints.

Ansburg & Dominowski (2000) explicitly based their approach on Ohlsson’s theory, by using practice problems that required Ohlsson’s proposed *elaboration* mechanism to solve. Their instructional component of training stressed looking for different interpretations of a problem. The specific focus on *goal* interpretation is reminiscent of Ohlsson’s mechanism of constraint-relaxation, proposed to change the cognitive representation of the goal state (Ohlsson, 1992, p.14). The approaches to training described here have therefore tended to focus on the interpretation either of the given situation (assumptions) or of the goal. Therefore, we decided to compare the effects of combined barrier and assumption training with both of these approaches.

# Experiment

The aim of the experiment was to investigate whether participants given training in overcoming perceived barriers and implicit assumptions would demonstrate improved performance in solving insight problems over control participants. In addition, the experiment examined the effects of barrier training alone, assumptions training alone, and goal training.

## Method

### *Participants*

The participants were 120 student volunteers from the University of Victoria, 77 female and 43 male. No age information was collected. All had English as a first language.

### *Materials*

#### *Training*

There were four training conditions — assumption, barrier, goal, and integrated (combining assumption and barrier) and two control conditions. All six conditions consisted of a set of instructions and used the nine dot problem (Scheerer, 1963) as a practice problem. Participants were first given the practice problem, and then the instructions were provided and their application illustrated in the context of the practice problem. The script for assumption training was based on that used by Cunningham and MacGregor (2008) while the control condition scripts aimed at providing "placebo" instructions, based on the content of the control instructions used by Ansburg and Dominowski (2000). The integrated instructions were somewhat longer, at 116 words, than those of the other three training scripts (80 to 96 words). This is the reason for two control conditions, the longer control script having 114 words, the shorter, 85. The scripts are shown in Appendix 1.

#### *Test*

The eleven test problems were selected because they were judged as likely to involve insight problem solving, based either on previous usage or from the principles required to solve them.  Three were "matchstick arithmetic" problems, one each of Types A, B and C, as defined by Knoblich et al., (1999).  These were selected because their solutions are considered to require the mechanism of constraint relaxation (Knoblich et al., 1999). The problems, solutions, hypothesized solution principles, and sources are provided in Appendix 2.

*Design and Procedure*

The experiment used a between subjects design with six levels of training.  Participants were randomly assigned to conditions, with the constraint of 10 in each cell.  Participants were tested in individual sessions lasting approximately one hour.

After receiving training, the eleven test problems were presented individually, the three matchstick problems first, followed by the remaining eight spatial problems presented in the same random order.  Four minutes were allowed for each problem, and participants were aware of the time limit.  Reminders of the training instructions for each condition were given at the one and three minute points.

Results and Discussion

For each participant scores of one and zero were assigned to correct and incorrect solutions, respectively, and averaged across all 11 problems.  The mean solution rates for each participant were submitted to a one way analysis of variance, with training as independent variable and average solution rate as dependent variable.

The mean solution rates for problems (and standard deviations) were 0.72 (0.19), 0.58 (0.21), 0.52 (.14), 0.42 (0.22), 0.50 (0.21) and 0.48 (0.17) for the integrated, barrier, assumption, goal, and long and short control conditions, respectively.  The results of the overall analysis of variance were highly significant, $F(5,114)=25.78$, $MSe=0.04$, $p<0.001$, $\eta 2=0.20$.  Post hoc comparisons indicated that solution rates in the integrated condition were significantly higher than in all other conditions ($p<0.05$). In addition, barrier training was significantly more effective than goal training. No other differences were significant.

The experiment was conducted to test the effectiveness of a combination of barrier and assumption training on insight problem solving. The results indicated that the procedure was effective compared to performance in a control conditions and in alternative training conditions. Importantly for present purposes, the combined training was more effective than either assumption or barrier training separately. The finding is consistent with the proposed conceptualization of a relationship between barriers and assumptions. That is, the barrier training component of the combined procedure may assist in identifying implicit assumptions, while the assumption training component facilitates releasing the constraints that those assumptions impose. Future research will obtain verbal protocols to examine more directly whether combined training does indeed work in this way. Verbal protocols may also reveal whether participants in other conditions who successfully solve do so by spontaneously adopting this type of strategy. A limitation of the present study is that spatial problems only were used. Future research will test whether the findings extend to other forms of insight problem.

## General Discussion

We proposed that during problem solving activity, the person may become conscious of something they see as impeding their progress towards the goal. This perceived barrier arises from the initial, unproductive, representation of the problem, and may therefore provide cues either to the existence of restrictive assumptions or to alternative problem representations. Because the perceived barrier is a manifestation of tacit assumptions, it may provide a point of leverage for shifting the representation into a more productive form. From this perspective, it may be possible to facilitate restructuring through instructional interventions aimed at assumptions and barriers. However, in the present case, training and testing were limited to spatial problems only, and whether the findings generalize to other types of problem will require additional research.

We conducted an experiment to test the effectiveness of several training interventions on insight problem solving. The results supported the conceptual distinction we made, between the role of assumptions and barriers in insight problem solving. Perceived barriers may provide a conscious focus and direction to problem solving activity. This may be unproductive, if the activity becomes fixated on the barrier, or productive, if cues from the barrier help to identify and release constraining assumptions. The results also add to the growing body of findings that insight problem solving may be facilitated by relatively brief training interventions (Ahmed & Patrick, 2006; Ansburg & Dominowski, 2000; Chrysikou, 2006; Cunningham & MacGregor, 2008; Dow & Mayer, 2004; Wicker, Weinstein, Yelich, & Brooks, 1978).

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**Appendix 1 – Experiment Training Scripts**

*Assumptions Training Script:*

I will be giving you some reminders throughout the session:

1. Are your first impulses misleading?

2. If you are stuck, is it because you are making a wrong or an unnecessary assumption?

Let's see if the two pieces of advice help you on some further problems. As you tackle them, try to remember to ask yourself:

1. Are your first impulses misleading?

2. If you are stuck, is it because you are making a wrong or an unnecessary assumption?

*Goal Training Script:*

I will be giving you some reminders throughout the session:

1. When you think about what you are focusing on trying to do right now, are you focusing on the right goal?

2. What is the goal of the task again?

Let's see if the two pieces of advice help you on some further problems. As you tackle them, try to remember to ask yourself:

1. When you think about what you are focusing on trying to do right now, are you focusing on the right goal?

2. What is the goal of the task again?

*Barrier Training Script:*

I will be giving you some reminders throughout the session:

1. What is it that is getting you stuck or is getting in the way?

2. If you can’t change this, what is the challenge you are faced with now?

Let’s see if the two pieces of advice help you on some practice problems. As you tackle them, try to remember to ask yourself:

1. What is it that is getting you stuck or is getting in the way?

2. If you can’t change this, what is the challenge you are faced with now?

*Control Training Script (shorter version):*

So I will be giving you some reminders throughout the session:

1. Is there a principle or fact you may not be remembering?

2. Is this problem difficult because it is difficult to keep track of?

Let’s see if the two pieces of advice help you on some practice problems. As you tackle them, try to remember to ask yourself:

1. Is there a principle or fact you may not be remembering?

2. Is this problem difficult because it is difficult to keep track of?

*Combined Barrie/Assumption Training Script:*

1. What do you find yourself focusing on? What strategies have you been trying?

2. Why are you using these/this strategies? What are you trying to do? And why do you want to do that? What is actually important to you? Is your strategy working? Why not? What is getting in the way?

3. And what assumptions are you making? What are you assuming is necessary in order to solve this problem?

4. What is posing a barrier for you? And how is that getting in the way? What makes that a problem? What bugs you about it? So what are you really trying to do? What is your real challenge? What is the real problem?

*Control Script (longer version):*

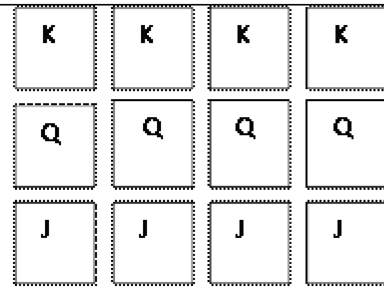
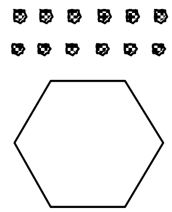
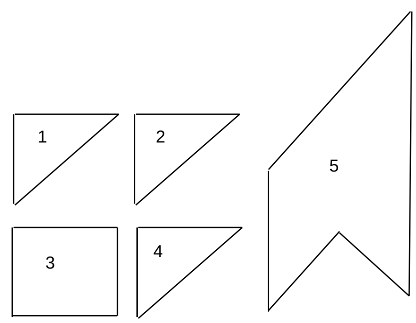
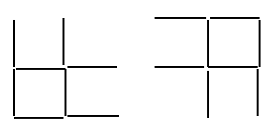
1. What do you find yourself focusing on? What strategies have you been trying?

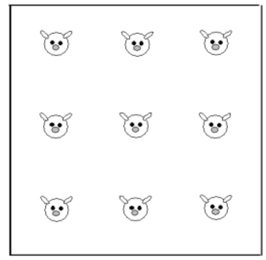
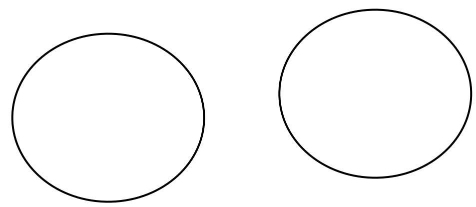
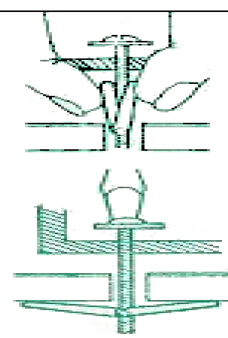
2. Why are you using these/this strategies? What are you trying to do?

3. What is the task again? What was the original problem as it was set out? What was your original goal? Could the task involve some sort of principle, concept, or fact that you already know but haven't considered?

4. Could it be that you are simply not remembering something? Would it help to scan your memory for similar problems such as this? Is this problem difficult to keep track of? Are you keeping track of what you have tried and haven't tried, of all the possibilities?

Appendix 2 – *The Problems: Task and Materials*

| Task required | Illustration of materials |
|---|---|
| 1. Cards: Materials: Twelve cards from a standard deck, 4 Kings, Queens, Jacks.. The task is to arrange them in a grid –a table—so that each row and each column contains only one Jack, one Queen and one King. Source: Cunningham and MacGregor (2008) |   |
| 2. Hexagon: Materials: 12 discs and Hexagon The task is to arrange the 12 discs so that each side of the hexagon has 4 discs? Source: Cunningham, MacGregor, Gibb, & Harr (2009) |  |
| 3. Cross: Materials: Five pieces of wood (as shown on right). The task is to arrange the 5 pieces to form a cross (like a plus sign). Source: Adapted from the T-puzzle, Suzuki, Abe, Hiraki, & Miyazaki (2001) |   |
| 4. Sticks. Materials: 8 matchsticks. The task is to move three sticks and change the pattern on the left to look like the pattern on the right? Source: Adapted from Kokinov et al., (1997) |  |

| | |
|---|---|
| 5. Diagram of pigs in a pigpen.<br>The task is to add two squares so that each of the 9 pigs ends up in a separate enclosure. Answer shown here was not shown to subjects. Source: Gilhooly & Murphy (2005); Isaak and Just (1996) |  |
| 6. 8 pieces of wood that fit to form two circles representing two plates. The task is to arrange the pieces of wood so that they fit together in a coherent form.<br>Source: New Problem |  |
| 7. Materials: a round wire clamp that tightens by overlapping two ends and pushing the two ends apart with a screw configuration as opposed to ‘cinching’ or pulling the ends together, and a piece of black plastic 4 inch tubing. The task is to attach the clamp firmly around the plastic pipe.<br>Source: New problem |  |
| 8. Screw Materials: toggle bolt, 18 x 4 x 4 wooden box, piece of metal to attach to the front of the box The task is to tighten the screw with a screwdriver so that the metal piece is firmly attached to the hollow beam, without reaching or looking inside the beam.<br>Source: New problem. |  |