

“Staring you in the face: an investigation of the role of training in generating constraint in problem solving activities”

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Abstract

This between participants study investigated whether training given to participants ($N = 32$) in an arithmetic problem solving test involving matchstick Roman Numerals (RNs) would have an impasse effect on problem solving ability. The hypothesis predicted that those participants trained in both RNs and Operators would perform better than those trained only in RNs. To provide a further test for the hypothesis, participants were also given two different types of problem to solve. The aim of the study was to determine whether the provision of training could cause a fixation that would affect problem solving, and it replicated an earlier test by Knoblich, Ohlsson, Haider and Rhenius (1999). The main finding of the study was that participants trained in RNs and operators were able to solve more problems where operators had to be manipulated than they could problems that required a numeral to be altered, with the exact opposite presented by those training only in RNs. In a 2 X 2 ANOVA, the results were not found to be significant and there was no interaction between the variables.

Introduction

Why do humans often face a frustrating impasse when trying to solve a problem when the answer is quite literally staring them in the face (Chronicle, Ormerod & MacGregor, 2001), or if the problem solver is competent and knowledgeable enough to solve the problem (Knoblich, Ohlsson, Haider & Rhenius, 1999)? Problem Space Theory offers the notion that people use pre-existing knowledge and heuristics to investigate a path to the goal state and solve the problem (Newell & Simon, 1972; as cited in Eysenck, 2000). According to Knoblich *et al.*, it is precisely those tools which result in impasse: use of prior experience is automatic and unavoidable, and biases the representation of the problem. Gilhooly and Murphy (2005) argued that “a problem exists when someone has a goal for which they are unable to generate a suitable sequence of actions either from memory or by applying a routine method” (p. 279). Gilhooly *et al.* propose that people generate a representation of the problem and then search for a sequence of actions within its framework. In their study, based on the nine-dot problem, Chronicle *et al.*, argued that there was a cognitive base to this particular

problem's difficulty in that the cognitive processes of visual perception caused the fixation of a mental representation of the dots as a square, rendering the problem unsolvable. Chronicle *et al.* were particularly interested in how training and instruction affected problem solving performance, and found that even when participants were given specific instructions to ignore this initial representation, their perceptual organisation took precedence. In their study of autobiographical memory retrieval and problem solving, Williams, Chan, Crane, Barnhofer, Eade and Healy (2006) found that voluntary retrieval from memory is hierarchical taking its starting point from an elaboration of the cue.

Knoblich, Ohlsson, Haider and Rhenius (1999) conducted a study using matchstick Roman Numerals (RNs) to provide an explanation for the "exploration – impasse – insight – execution" phenomena. They predicted that people's experience and knowledge of arithmetical problems would act as a constraint on their ability to solve matchstick problems, particularly those that involved making a change to an equation's operators (e.g., "+") or those that breached the rules of tautology which sets an expectation for how an arithmetic statement should appear. Knoblich, Ohlsson and Raney (2001) repeated the experiment using eye movement as a measure to support their prediction that participants would spend more time focusing on the values in the equation rather than the operators as the key to the solution, and that towards the end of a successful problem solving activity, more attention would be paid to the operators. In both cases, the results supported their predictions. In both studies, participants were given training in RNs prior to testing to speed up RN recognition.

The present study focused specifically on this training with the aim of investigating the extent to which the training in RNs affected the results. According to Chronicle, Ormerod and MacGregor (2001) there should be little if any effect of training on problem solving performance, whereas the results of Williams, Chan, Crane, Barnhofer, Eade and Healy (2006) would indicate that there may be an effect. The study here replicated Knoblich, Ohlsson, Haider and Rhenius' (1999) experiment, focusing specifically on the affect of training on problem solving performance. Participants were trained in RNs only, or in both RNs and operators, and given problems that could either be solved by manipulating the numerical value or the operator. The study predicted that those people who were given training in RNs plus operators would achieve higher scores. The study sought to understand whether the act of training in RNs had inadvertently caused a fixation on RNs – and therefore a constraint to hunt for the solutions only amongst the numerical values as being the most immediately retrievable cues from memory - in Knoblich *et al.*'s studies.

Method

Design

The study used a between participants experimental design to measure participants' ability to solve 6 arithmetic problems accurately within a timescale of 10 minutes, having been given training in either RNs only or RNs and operators. The problems consisted of inaccurate arithmetical statements using Roman Numerals and operators constructed from matchsticks. Participants were tasked with moving one single matchstick within the statement to render the statement accurate. Participants were then given one of two types of problems: (a) problems that could be solved by a simple manipulation of the value in the arithmetic equation, or (b) problems that required a change in the operator to facilitate solution. Participants were scored based on correct arithmetic statements achieved by moving one single matchstick to a different position in the statement (correct statement = 1, wrong or uncompleted statement = 0). The training / problem type variables were measured using a ratio scale.

Participants were positioned sufficiently apart from each other such they were unable to see each other's papers, and an independent researcher, who was unaware of the intention of the study, provided the participants with their instructions, training papers and problem papers. The problems used in the study (which are contained in the Appendix) were the same as those used by Knoblich, Ohlsson, Haider and Rhenius' (1999).

Participants

The participants were adults (N = 32, m = 41%, f = 59%, mean age = 33.19, SD = 10.04) voluntarily sampled from the psychology classes of a Higher Education Access college. Participants responded to an advert posted on the college noticeboard. They were informed that the study was part of a University student assignment, that no personal data would be collected and that participants could withdraw from the experiment at any time. Participants did not receive any reward or course credit.

Materials

Each participant was presented with a paper containing exactly the same instructions, apart from the inclusion of Operators in one group's briefing papers (see Appendix A). These were collected after the study period, and replaced with a paper containing six matchstick problems, with half of the participants being given problems that required an operator to be altered, and half given problems that required a Roman Numeral to be altered (see Appendix B). At the end of the test, participants were asked to indicate their gender and age on the back of their papers.

Procedure

The experiment was conducted over three sessions in a classroom on the college campus. Participants were given a verbal briefing prior to the training. Participants were asked to select a letter at random from a hat, which indicated which training group they would be assigned to. They were then given a sheet of paper containing a repeat of the instructions given verbally, plus a list of RNs with their numerical equivalent and, in the case of the RN + Operator trained group, a list of all operators with an explanation of their meaning. Participants were asked to study this for 5 minutes. The papers were then collected, and participants were given the problem papers: they were given 10 minutes to complete as many of the problems as possible. At the conclusion of the experiment, participants were given a verbal de-briefing on the nature and hypothesis of the study.

Results

The present study sought to determine if there would be an effect of training on constraint in solving arithmetic problems constructed from matchsticks, and also whether there would be a difference in performance depending on type of problem presented. Mean problems solved for each group are shown in Table 1. Participants trained in both Operators and Roman Numerals (RNs) performed better with Operator-type problems than those trained in RNs only, but performed worse with problems that could only be solved by manipulating a numerical value. The mean scores for both groups for all problems solved are identical (mean = 2.94, SD = 2.144). It was noted that the deviations in the mean scores for operator problems were proportionately very high indicating considerable variance in the scores.

Table 1 Mean scores as a function of Type of Training Given and Problem Type

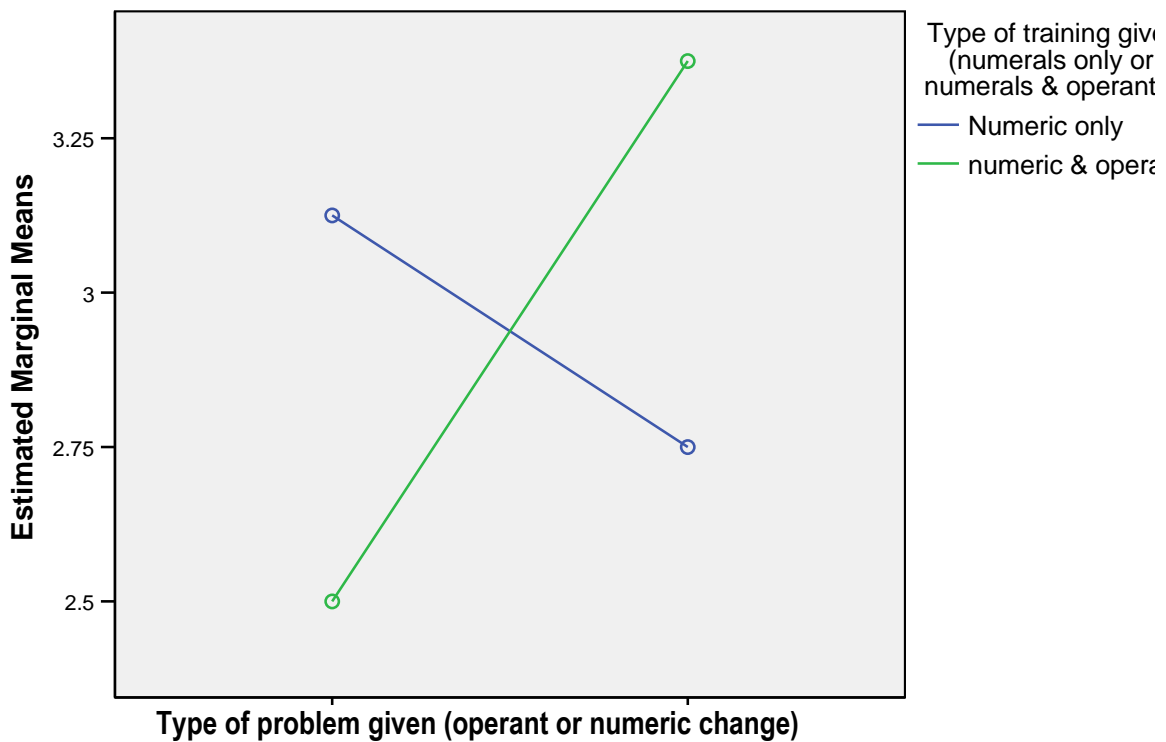
		Problem Type	
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		Roman Numerals	Operators	Totals
Type of Training Given	Operators and Roman Numerals	2.50 (1.604)	3.38 (2.615)	2.94 (2.144)
	Roman Numerals Only	3.13 (1.808)	2.75 (2.550)	2.94 (2.144)

Data were analysed using a 2 (training type) x 2 (problem type) ANOVA. There was no significant effect of problem type ($F(1,28) = 0.104, p > 0.05$) or type of training given ($F(1,28) = 0.0, p > 0.05$). There was also no interaction of type of training given and type of problem ($F(1,28) = 0.652, p > 0.05$), as shown in Figure 2. The null hypothesis cannot therefore be rejected.

Figure 2:

Estimated Marginal Means of Number of problems solved



Discussion

Knoblich, Ohlsson, Haider and Rhenius (1999) found that people's prior knowledge of arithmetic problems acted as a constraint on solving problems involving Roman Numerals (RNs) particularly where the solution lay in manipulating an element of an operator or breaching tautology rules. The present study predicted that the act of providing participants with training in RNs beforehand in the form of briefing sheets would have an effect of constraint on problem solving abilities. To test this prediction, the study trained two groups of participants differently: one group was briefed on RNs only, while the other was trained in both RNs and Operators. If the hypothesis was supported, those participants trained in both RNs and Operators should perform better at both types of problems (RN solutions and Operators solutions). RN and Operator trained participants did perform better with problems involving Operators but not those involving RNs. Although not significant, there is clearly something of interest here: one explanation based on the earlier work of Gilhooly and Murphy (2005) could be that participants trained in Operators and RNs generated more complex representations of the problems and used more actions to reach an end solution than those who were only trained in RNs. Alternatively, as Operator items comprised the last section on the training sheets given to participants, these elements remained most readily accessible in short term memory and that participants tended to look for solutions involving operators before any others, whereas those trained in RNs only spent more time looking for solutions within numerical values. However, it should be noted that the small size of the sample, and the nature of the participants (psychology students) could have influenced the results, and it is also possible that the ability to solve these particular type of problems require a particular mathematical and / or logical reasoning ability – irrespective of any training given - that is not necessarily a common skill or talent.

There is still considerable work to be done in the area of understanding problem solving and the issues of constraint. The present study was small scale and would have benefited from a much larger sample. It would also be of interest to apply other strategies for training type, including a temporal variable.

References

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APPENDIX A

A: PROBLEM SOLVING EXPERIMENTAL RESEARCH

Pre-Problem Solving test familiarisation

The short problem solving test that you are about to engage with involves the use of Roman Numerals. Take a few moments now to study this familiarisation paper to ensure that you understand Roman Numerals. You will be given five minutes to study the information below. After this time, this paper will be retrieved by the researcher and you will be given the problem solving test paper, text side down. Please write your age and "m" for male or "f" on the back of this sheet when you get it. You can withdraw from the test at any time during or after the test is completed.

When the researcher indicates, you should turn over the paper and solve as many of the problems as you can within the 10 minute time slot. If you finish before the 10 minute period is up, please turn your paper over so that it is text side down and write the time on the back of the paper. You should then wait until the test period is over, and all papers have been collected from all participants.

No information of a personal nature is being collected as part of this study.

Roman Numeral	Equivalent
I	1
II	2
III	3
IV	4
V	5
VI	6
VII	7
VIII	8
IX	9



B: PROBLEM SOLVING EXPERIMENTAL RESEARCH

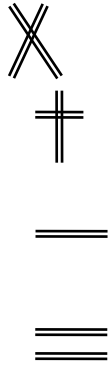
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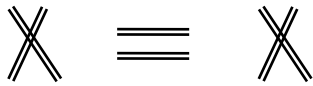
Roman Numeral	Equivalent
I	1
II	2
III	3
IV	4
V	5
VI	6
VII	7
VIII	8
IX	9



10
plus
Minus
equals



5 = 4 + 1



10 = 10

APPENDIX B

(Operator problems)

Please create a true statement for each problem below by rewriting the equation. You are permitted to move one matchstick for each problem.

Please write the solution in the space provided opposite each problem.

<u>Problem</u>	<u>Solution</u>
$ \equiv + $	
$VI \equiv IV = $	
$IV \equiv III = $	
$III \equiv III + III$	
$V \equiv III = $	
$IV \equiv IV + IV$	

Thank you for your time.

(Numeric problems)

Please create a true statement for each problem below by rewriting the equation. You are permitted to move one matchstick for each problem.

Please write the solution in the space provided opposite each problem.

<u>Problem</u>	<u>Solution</u>
$III = IV - III$	
$VII = III + III$	
$IV = II + IV$	
$XI = I + XII$	
$IV = III + VI$	
$IV = V + IV$	

Thank you for your time.