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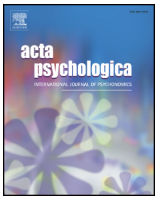

Insight with hands and things

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ABSTRACT

Two experiments examined whether different task ecologies influenced insight problem solving. The 17 animals problem was employed, a pure insight problem. Its initial formulation encourages the application of a direct arithmetic solution, but its solution requires the spatial arrangement of sets involving some degree of overlap. Participants were randomly allocated to either a tablet condition where they could use a stylus and an electronic tablet to sketch a solution or a model building condition where participants were given material with which to build enclosures and figurines. In both experiments, participants were much more likely to develop a working solution in the model building condition. The difference in performance elicited by different task ecologies was unrelated to individual differences in working memory, actively open-minded thinking, or need for cognition (Experiment 1), although individual differences in creativity were correlated with problem solving success in Experiment 2. The discussion focuses on the implications of these findings for the prevailing metatheoretical commitment to methodological individualism that places the individual as the ontological locus of cognition.

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1. Introduction

The psychology of problem solving has, over the years, split its research efforts tackling so-called analytic or transformation problems and insight problems. The former are well-defined problems with simple operators that can be applied to transform the initial problem presentation through a series of intermediate states—each intermediate state is a move in a logically specifiable problem space—to reach a desired configuration; the Tower of Hanoi or river crossing problems are good examples. In turn, insight problems are less well defined with no immediately obvious or effective operators that can be applied to transform the initial presentation into a solution. This is because insight problems are formulated in a manner that encourages a misleading interpretation and obscures a path to solution. For example, how can 17 animals be placed in four pens in such a manner that there is an odd number of animals in each pen? (to adapt a problem reported in Metcalfe & Wiebe, 1987). The problem masquerades as an arithmetic one, but an arithmetic solution is impossible (with whole animals/numbers); rather, a solution is possible when pens are projected as sets that can overlap.

The focus of the theoretical efforts for transformation problems is usually the effectiveness with which participants traverse the problem space, and performance is measured in the number and type of moves participants produce to reach the goal state. These efforts lend themselves to computational modelling of the move selection heuristics allegedly employed by participants. In turn, theoretical efforts for insight problem solving have focused on the processes that lead to a new interpretation, or restructuring of the problem representation that helps participants overcome an impasse and identify plausible solutions. The nature of the processes that result in insight has been the subject of some debate. One camp, inspired by Köhler's (1925/1957) ethnographic observations of the apparent suddenness of insight, suggest that largely unconscious and automatic processes evince a restructured mental representation of the problem—for example, Ohlsson's (1992) representational change theory and its more recent incarnation, redistribution theory (Ohlsson, 2011). Another camp holds that, like for transformation problems, insight solutions are distilled through conscious analytic processes that may or may not involve the restructuration of a mental representation (e.g., Fleck & Weisberg, 2004, 2013; Weisberg, 2015). There are two important features of the current debate about the mental processes implicated in insight problem solving. The first relates to the role of working memory; the second reflects a metatheoretical commitment to methodological individualism. Let's take each in turn.

If insight problem solving proceeds on the basis of a conscious analysis of the constituent elements of the problem and their relation, then one would expect measures of effortful cognitive analytical processing such as working memory capacity to be correlated with problem solving performance. On the other hand, if processing was largely unconscious, then working memory capacity might not be so relevant in the process

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of achieving insight. Using an individual differences approach, Gilhooly and Fioratou (2009) invited participants to solve series of insight and non-insight problems—from which composite performance scores were derived—and profiled their participants in term of verbal and visuo-spatial working memory using complex sentence, operation and visual pattern span tasks to determine the degree with which working memory measures correlated with the composite solution rate score for both types of problems. Verbal and visuo-spatial working memory span performance significantly predicted variance for *both* insight and non-insight problems. Gilhooly and Fioratou (2009) interpreted these findings in terms of the storage demands of keeping a rich problem representation in working memory such as to enhance the probability that "key elements (…) will be represented and available for reinterpretation" (p. 373). Working memory measures are strongly correlated with traditional measures of intelligence (e.g., Engle, Tuholski, Laughlin, & Conway, 1999; Oberauer, Schulze, Wilhelm, & Süß, 2005), and in turn measures of intelligence correlate with performance on insight problem solving (Davidson, 1995; Frederick, 2005). In like vein, research on individual differences in reasoning (e.g., Sirota, Juanchich, & Hagmayer, 2014; Stanovich & West, 1998) reveals that participants who score high on measures of intelligence, tend to engage in more rational thinking in a wide range of reasoning tasks. That research also implicates thinking dispositions in reasoning performance. Thus measures of open-minded thinking or willingness to engage in effortful thinking correlate with more rational thinking performance (Stanovich & West, 1998; Cacioppo, Petty, Feinstein, & Jarvis, 1996).

A focus on cognitive capacities and thinking dispositions reflects a deep and pervasive commitment to methodological individualism, defined by Malafouris (2013, p. 25) as "the foregrounding of the human individual as the appropriate analytic unit and ontological locus of human cognition". This commitment naturally encourages researchers to develop task procedures devoid of real-world meaning, goals and utilities, and that limit or prevent interactivity with the physical features of a problem, with the aim to identify 'pure' cognitive processes under controlled laboratory conditions (Vallée-Tourangeau & Vallée-Tourangeau, 2016). This commitment deflects attention away from the context of reasoning, and reinforces the focus on the capacities that an individual brings to a reasoning task. Yet, thinking and reasoning do not take place in a vacuum, and there is much evidence that systematic manipulations of task instructions, external representations, and artefacts can substantially transform deductive reasoning (e.g., Manktelow & Over, 1991), hypothesis-testing behavior (e.g., Gale & Ball, 2006; Vallée-Tourangeau, 2012; Vallée-Tourangeau & Payton, 2008), transformation problem solving (Guthrie, Vallée-Tourangeau, Vallée-Tourangeau, & Howard, 2015; Zhang & Norman, 1994), mental arithmetic (Carlson, Avraamides, Cary, & Strasberg, 2007; Lave, 1988; Vallée-Tourangeau, 2013), Bayesian reasoning (Vallée-Tourangeau, Abadie, & Vallée-Tourangeau, 2015) and insight problem solving (Weller, Villejoubert, & Vallée-Tourangeau, 2011). These context and representational effects encourage a transactional perspective on cognition. From this perspective, the cognitive capacities of the reasoner and the features of the context cannot be fruitfully segmented and their causal role defined orthogonally in the explanation of performance. A reasoner is embedded in a certain task environment that together configures a certain cognitive ecology within which certain cognitive abilities are manifested.

This transactional perspective encourages the exploration of the role of interactivity in problem solving (Steffensen, Vallée-Tourangeau, & Vallée-Tourangeau, 2016). In an interactive problem-solving environment, a problem is presented with manipulable constitutive elements. Take for example the matchstick arithmetic problems developed by Knoblich, Ohlsson, Haider, and Rhenius (1999). The problems employ roman numerals in the shape of matchsticks that configure false arithmetic expressions (e.g., XI = III + III) that can be turned true by moving one matchstick (e.g., VI = III + III). However, in the original procedure employed by Knoblich et al. (and in their subsequent eye tracking experiment, Knoblich, Ohlsson, & Raney, 2001), the problems are presented on a computer screen and participants cannot manipulate the problem elements (and in the eye tracking experiment, even the participants' movements are constrained by the requirement of biting into a bar to stabilize the head and ensure more accurate eye tracking data). Participants stare at the computer display and mentally simulate matchstick movement; the perceptual feedback is invariant. Performance on this task is substantially transformed using a procedure wherein participants can manipulate the matchsticks (Weller et al., 2011). Moving a matchstick changes the physical appearance of the problem, prompts and guides new actions, and insight solutions are enacted through this dynamic cycle. Actions need not be premeditated; rather, simpler perception-action loops may shape, at different stages of the problem solving trajectory, the evolving physical configuration of the problem (Vallée-Tourangeau et al., 2015). An interactive problem solving environment foregrounds the importance of actions and the changes in action affordances wrought by the changes in the physical appearance of the problem. These reflections on research methodology, and the findings reported in Weller et al., suggest that the task ecology and the type of interactivity that it permits are important determinants of problem solving performance, above and beyond internal resources such as working memory capacity.

1.1. The present experiments

The primary aim of the experiments reported here was to determine whether different types of interactivity within different task ecologies influenced insight problem-solving performance. Both experiments employed the 17A problem, a pure insight problem according to the classification offered in Weisberg (1995). The 17A problem presents itself as involving an arithmetic solution yet this is only possible through the spatial arrangement of sets involving some degree of overlap (see Fig. 1). Two different task ecologies were created. In one, participants were given artefacts to build a model of the solution. They could not sketch a solution using a pen; only the material with which to build enclosures and 17 animal figurines were provided. In the second task environment, participants were invited to sketch a solution using a stylus and an electronic tablet. In that condition, no artefacts could be manipulated to spark ideas as participants drew their solution of the problem on the tablet.

We predicted that the type of interactivity—afforded by the task ecologies—would determine successful performance with the 17A problem. We expected a substantially higher rate of solutions in the model building condition, and this for two principal reasons. First, without the means to write down numbers and doodle various arithmetic operations, the focus on an arithmetic solution should more quickly dissipate in the model building than in the tablet condition. Second, building a model of the solution forces participants to tinker with the shape and spatial arrangement of the enclosures. Thus actions may enact a different path to solution, one that does not involve the brute labour of dividing 17 into 4 odd numbers.

To explore the importance of internal resources in problem solving, we also measured participants' cognitive capacities and thinking

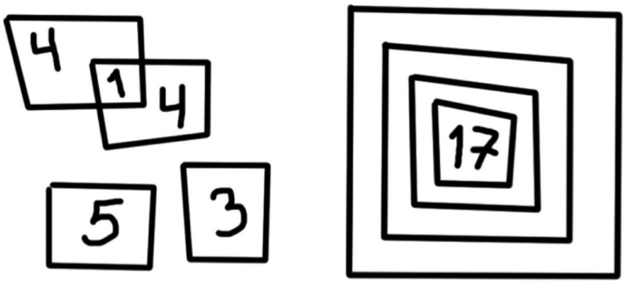

Fig. 1. Possible solutions for the 17A problem.

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