Cognition 119 (2011) 149–165

Contents lists available at ScienceDirect

Cognition

journal homepage: www.elsevier.com/locate/COGNIT

Mindset changes lead to drastic impairments in rule finding

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ARTICLE INFO

Article history:
Received 2 August 2010
Revised 24 November 2010
Accepted 9 January 2011

Keywords:
Mindset
Instructions
Rule finding
Problem solving
COVIS
Rule application

ABSTRACT

Rule finding is an important aspect of human reasoning and flexibility. Previous studies associated rule finding *failure* with past experience with the test stimuli and stable personality traits. We additionally show that rule finding performance is severely impaired by a mindset associated with applying an instructed rule. The mindset was established in Phase 1 (manipulation) of the experiment, before rule finding ability was assessed in Phase 2 (testing). The impairment in rule finding was observed even when Phase 1 involved executing a single trial (Experiment 2), and when entirely different stimuli and rules were used in the two phases of the experiment (Experiments 3–6). Experiments 4–6 show that applying an instructed rule in Phase 1 impaired subsequent (Phase 2) feedback evaluation, rule generation, and attention switching between rules, which are the three component processes involved in rule finding according to COVIS (Ashby, Alfonso-Reese, Turken, & Waldron, 1998).

1. Introduction

Detecting the rules or regularities which govern an environment allow people to predict future events and plan their actions. The ability to detect such environmental regularities, which we refer to as rule finding ability, is therefore a fundamental human capacity (Bunge, 2004; Jasso, 2001).

Rule finding takes part in a wide range of domains including category learning, problem solving, language, implicit learning (Hahn & Chater, 1998) and is a central process in adjusting to new situations (Jasso, 2001). It is used in a variety of everyday situations (Heider, 1958; Jones & Davis, 1965), especially when these situations are novel, require decision making or creativity (e.g., Frensch & Sternberg, 1989; Hesketh, 1997; Sternberg, 1996; Sternberg & Frensch, 1992), including in scientific inquiry (e.g., Klahr & Dunbar, 1988; Lakatos, 1970).

In the lab, rule finding is exemplified in a variety of paradigms such as Rule Based Category Learning (Ashby, Alfonso-Reese, Turken, & Waldron, 1998), the Wisconsin Card Sorting Test (Berg, 1948), Jar Problems (Luchins, 1942), Raven's Progressive Matrices (Raven, 1962), letter series (Thurstone, 1962) analogies (Sternberg, 1977), and so forth. Common to all these paradigms is that one has to generate rules and test their validity continuously until the correct rule is found (Tachibana et al., 2009). In some paradigms (as Rule Based Category Learning and the Wisconsin Card Sorting Test) external feedback is provided for every attempt to test a hypothesized rule and in other paradigms (as Raven's Progressive Matrices and insight problems) there is no such external feedback and the continuous testing of hypothesized rules cannot be directly observed.

Rule finding has been studied using a variety of research approaches. First it was referred to as a stable ability domain related to fluid intelligence and working memory (e.g., Blair, 2006; Gustafsson, 1999; LeBlanc & Weber-Russell, 1996; Lehto, 2004; Maddox, Ashby, Ing, & Pickering, 2004; McCrae, Arenberg, & Costa, 1987; Runco, 2007; Swanson & Sachse-Lee, 2001; Waldron & Ashby, 2001; Wittmann & Süß, 1999; Zeithamova & Maddox, 2006). Second, it was treated as a major process in explicit category learning (e.g., Bruner, Goodnow, & Austin, 1956; Levine, 1975; Restle,

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doi:10.1016/j.cognition.2011.01.002

1962; Trabasso & Bower, 1968). An example can be found in Ashby et al.'s (1998) influential Competition between Verbal and Implicit Systems (COVIS) model. COVIS assumes that there are two systems involved in category learning. One system is implicit and is dominated by a procedural-learning. Of greater relevance here is the second, explicit system for Rule Based Category Learning. Arguably, this system is based on rule finding and depends heavily on working memory and executive attention (Waldron & Ashby, 2001; Zeithamova & Maddox, 2006). This system operates for example when one is required to find an explicit categorization rule based on correct/incorrect feedback. In this task, one starts by generating a candidate rule and storing it in working memory. This candidate rule remains active until feedback disconfirms its validity. At this point, *feedback evaluation* mechanisms must be able to process the feedback and trigger a behavioral change. The behavioral change which follows the negative feedback involves generating new candidate rules, requiring *rule generation* ability. Furthermore, attention must be switched away and disengage from the old rule, move to the new rule and engage in it, operations which together make *attention-switching* ability. COVIS therefore states that these three processes are essential for successful rule finding.

The literature also considered factors responsible for rule finding *failures*. Most of the studies in this area emphasize the role of past experience as the cause of such failure, sometimes referred to as "fixedness" (Duncker, 1945; Lewin, 1936; Luchins, 1942). In Berg's (1948) Wisconsin Card Sorting Test, fixedness is indicated by *perseverative responses* in which participants continue to sort according to the previously relevant but no-longer relevant sorting rule. Luchins (1942); Luchins & Luchins, 1959, see also Atwood & Polson, 1976; Chen & Mo, 2004; Delaney, Ericsson, & Knowles, 2004; Lippman, 1996; Lovett & Anderson, 1996), in a series of experiments using the water jar task, showed that once a rule is found, participants adhere to that rule and continue using it even when simpler rules are equally effective in reaching the solution. Analogously, Schwartz (1982) found that when reinforcing a specific response sequence, a stereotyped response is developed. Moreover, he showed that if a history of successful stereotyped responses was created, participants found it difficult to find new response sequences that would generate the desired outcome. Schwartz (1982) concluded that the critical factor is being given a reward because rewards teach participants to concentrate on reward production instead of focusing on finding new ways to generate rewards.

Fixedness arguably reflects a difficulty in observing more than one dimension of a stimulus (Kaplan & Simon, 1990; Knöblich, Ohlsson, & Raney, 2001; Langer, 1989; MacGregor, Ormerod, & Chronicle, 2001; Seifert, Meyer, Davidson, Patalano, & Yaniv, 1995). This form of rigid encoding (e.g., Robinson-Riegler & Robinson-Riegler, 2004; Willingham, 2004) precludes inputs that were proven irrelevant in the past from influencing performance (Willingham, 2004; Yaniv & Meyer, 1987). Knöblich, Ohlsson and their colleagues (Knöblich, Ohlsson, Rhenius, & Haider, 1999; Knöblich et al., 2001) emphasize the role of the set of constraints, learned in the past, that define how familiar stimuli are regarded as well as the fact that these familiar stimuli create meaningful patterns, or chunks.

Langer and colleagues (Langer, 1989, 2000; see also Chanowitz & Langer, 1981; Langer & Piper, 1987) use the term "mindless thinking" to describe a phenomenon analogous to fixedness. According to them, mindless thinking occurs when a problem's context is presented in absolute (e.g., "this *is* an eraser") rather than probabilistic terms ("this *could be* an eraser"). Accordingly, Langer (1989, 2000) emphasized the role of the "first encounter" with the stimulus. She argues that if a stimulus is presented in an absolute manner in the first encounter, a premature cognitive commitment is created to the specific dimension emphasized in this encounter. This could be, for example the commitment to the interpretation of an eraser as an erasing device as opposed to a potential cork for a bottle, for example. Such commitment creates a difficulty in observing other dimensions of this stimulus later on. If on the other hand, one uses probabilistic terms during the first encounter, this over-commitment is not created, a fact that makes it easier to consider these potential dimensions when needed. Thus, according to Langer (1989), the terms used during the first encounter with the stimulus dictate if focusing on the stimulus would be narrow and rigid vs. flexible.

Although as seen from our brief review, most of the literature emphasizes past experience with the task's stimuli or actions, there is growing evidence that the state of mind, also called mindset or "psychological context", plays an important role in problem solving (Duncker, 1945; Galinsky & Kray, 2004; Gollwitzer, 1990; Kounios et al., 2006). What we call "mindset" can be described as *a configuration of processing resources that are made available for the task at hand as well as their suitable tuning for carrying it out*. This configuration lasts until the situation signals that a change is required. This definition resembles Duncker's (1945) definition of mindset as a state of mind that a participant brings to a task; any preparatory cognitive activity that precedes thinking and perception.

For example, according to the COVIS model, rule finding requires that at least 3 processing resources would be made available: feedback evaluation, rule generation, and attention switching between rules (Ashby et al., 1998). An appropriate mindset for rule finding should therefore include the activation and proper tuning of these resources. Namely, when one adopts a mindset appropriate for rule finding, one should be ready to evaluate feedback, generate rules, and switch among rules. The literature further shows that related mindsets are associated with unique brain states. Specifically, using functional neuroimaging techniques, Kounios et al. (2006) showed that the brain state recorded *before* the problem was presented predicted the nature of the solution as insight-based or not. In another study, Kounios et al. (2008) showed that individual differences in resting-state brain activity recorded before problem solving predicted the proportion of insight vs. non-insight problem-solving strategies used. Another evidence for mindset comes from the work of Galinsky and colleagues (Galinsky & Kray, 2004; Galinsky & Moskowitz, 2000; Kray & Galinsky, 2003). These studies involve a mindset created by considering the possibility that the reality could have