ARTICLE IN PRESS

Cognition xxx (2011) xxx–xxx

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
Available online xxxx

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 turned differently than it did. Such a mindset established prior to problem solving has been shown to *improve* performance in subsequent creativity tasks such as the Remote Associates Task (Mednick, Mednick, & Mednick, 1964, see Kray, Galinsky, & Wong, 2006) and Duncker's (1945) candle problem (Galinsky & Moskowitz, 2000).

As stated earlier, what appears to us as a core implication of COVIS (Ashby et al., 1998) is that rule finding requires the recruitment of the resources needed for feedback evaluation, rule generation and rule switching. As such, rule finding involves a special mindset that differs quite markedly from situations in which the rule is already known and needs only to be applied. We therefore make a distinction between two mindsets: one enabling rule finding and one accompanying applying an instructed rule.

The distinction that we have just made between two mindsets resembles to some extent Langer's (1989, 2000) distinction between mindful problem solving, invoked by probabilistic presentation of stimuli, and mindless problem solving, invoked by the presentation of stimuli in absolute terms. Specifically, Langer's probabilistic presentation of the test stimuli probably enables using the resources required for observing different dimensions of stimuli, something that probably does not occur when the stimulus is presented in absolute terms. The crucial difference between Langer's approach and our approach is that she emphasizes the role of the particular stimuli whereas we emphasize the role of the mindset that operates irrespective of the particular stimuli. We will return to this point in the General Discussion.

The exploration–exploitation literature suggests further evidence for distinct processing modes that resemble to some extent the mindsets that we discuss here. According to these studies, organisms adjust their attentional allocation between focused exploitation of known aspects of an environment versus the exploration of unknown components (Ishii, Yoshida, & Yoshimoto, 2002; Kaelbling, Littman, & Moore, 1996; Sutton & Barto, 1998). The requirement to find a rule is obviously analogous to exploration. In fact, rule finding theory (e.g., Ashby et al., 1998) suggests that a part of rule finding involves exploration of possible rules. Moreover, correct application of the identified rule leads to reward (reflected in positive feedback) which is again analogous to exploration aimed at finding sources of reward. Similarly, rule application is analogous to exploitation since when the rule is given there is no need to explore rules in order to find the source of rewards.

Our distinction is also analogous to some extent to the distinction between System 1 and System 2, as introduced by Stanovich and West (2000). The analogy here, though, is not as close as in the preceding example. According to Stanovich and West, System 2 is slow, operates sequentially, has low processing capacity and it requires high effort. It is considered to rely on executive resources similar to those described by Asby et al.'s COVIS (1998) in reference to explicit category learning. This system enables abstract thinking, hypothetical thinking, and inhibition (Evans, 2003). Based on this description, it is obvious that rule finding involves System 2 resources. The analogy breaks down when System 1 is considered. System 1 arguably represents universal cognition. It includes instinctive behavior and processes formed by associative learning. Its functioning is based to a large extent on finding similarities to existing knowledge (Evans, 2003). It is unclear at all whether System 1 is involved when participants are required to apply an analytic classification rule, a task which may sometimes be quite complex especially when the rule in not intuitive in nature.

Finally, a similar notion of mindsets was offered by Gollwitzer and his colleagues (Fujita, Gollwitzer, & Oettingen, 2007; Gollwitzer, 1990; Gollwitzer, Fujita, & Oettingen, 2004). These authors studied the difference between situations in which one is asked to make a decision and choose a goal and situations in which one has already chosen a goal and just needs to implement it. Gollwitzer and colleagues suggest that these two stages are associated with distinct mindsets: a deliberative mindset and an implemental mindset. In general they described the deliberative mindset as creating open mindedness (Fujita et al., 2007) and the implemental mindset as creating closed mindedness (Gollwitzer et al., 2004). It might be said in Gollwitzer's terms that the rule finding mindset and the mindset associated with following an instructed rule represent two different classes of implemental mindsets since in both cases, the behavioral goal is already known. Despite of that, we show that these two mindsets are associated with marked information processing differences. Given the reasonable assumption that it takes time (or actual task involvement) to recruit the resources required for rule finding, our prediction was that rule finding performance would be impaired when it immediately follows a state in which the response rules are known. In the present work, this state was induced during Phase 1 of the experiment by having participants apply an instructed analytic classification rule. Note that many cognitive tasks require just that: to follow an instructed classification rule. However, in a typical setting, experimenters tell participants to maintain high accuracy and speed. Maintaining the subtle balance between these two conflicting requirements involves executive resources such as feedback evaluation. To prevent that from happening, the instructions that were given in Phase 1 of our experiments did not require high speed or accuracy.

We hypothesized that since the processes required for rule finding are effortful and resource-consuming, when asked to operate according to an instructed rule in a manner that requires minimal employment of executive resources, participants would quickly learn that these resource-consuming processes are not needed and would turn them off. We measured rule finding ability during Phase 2 of the experiment by a Rule Based Category Learning task in which participants were required to find a response rule based on the experimenter's correct/incorrect feedback. It is important to note that this task cannot be considered as simple pattern recognition but rather as one involving explicit rules. Thus we assumed (and later confirmed) that it involves all the critical components stated by the explicit category learning system of COVIS (Ashby et al., 1998).

In Experiments 1–3, we tested the aforementioned hypothesis and examined the boundaries of this phenomenon. To anticipate, our results show immediate and drastic

Please cite this article in press as: ErEl, H., & Meiran, N. Mindset changes lead to drastic impairments in rule finding. *Cognition* (2011), doi:10.1016/j.cognition.2011.01.002

impairment in rule finding following application of an instructed rule. In Experiments 4–6 we examined the influence of applying an instructed rule on subsequent performance on tests tapping the three component processes involved in rule finding according to COVIS (Ashby et al., 1998), namely rule generation, feedback evaluation and attention switching between rules.

2. Experiments 1–3

All the experiments consisted of two phases. Phase 1 involved the manipulation of the mindset and Phase 2 involved testing the outcomes associated with the established mindset. In Experiments 1–3, Phase 2 always involved the rule finding task. Phase 1 (manipulation) involved the experimental condition associated with applying an instructed rule (henceforth, Instructed Rule) that was compared with two other conditions: Rule Finding (in Phase 1), or no activity (Baseline). Importantly, Phase 1 activity was intended to establish the psychological context (mindset) rather than creating a specific habit associated with particular stimuli.

Specifically, participants were first notified that the experiment involves two phases (except for the Baseline group who performed only Phase 2). They were further told that they will receive the instructions for Phase 2 immediately upon completion of Phase 1. The instructions for Phase 1 differed between the conditions. Participants in the Instructed Rule group were given the rule to apply. Participants in the Rule Finding group were told to find a response rule concerning the given set of stimuli based on the correct/incorrect feedback. The instructions for Phase 2 were the same as those given to the Rule Finding group during Phase 1 except for emphasizing the fact that the rule is new. These instructions were identical across groups.

The participants found the rule by using the correct/incorrect feedback which followed each response they made. To ensure that explicit rule finding is involved, it was explained to the participants that they should think of possible rules and test them according to the feedback. Participants were further told that this phase will end when the computer will recognize a series of consecutive successful responses indicating that the rule was found. For the participants in the Instructed Rule group, it was explicitly mentioned that Phase 2 involves a different rule and a different task than Phase 1 and that in this phase they are required to find a rule instead of simply applying it. Importantly, each phase involved the same rule for all the groups (except of course for the Baseline group who did not perform Phase 1) and the rule used in Phase 1 was always different from the rule used in Phase 2.

Each trial (in each phase) consisted of the presentation of a test stimulus (a letter-digit compound in Experiments 1 and 2, or a compound of two geometric shapes in Phase 1 of Experiment 3) related to a response rule such as: " If the (beginning/end) position of the letter in the ABC matches the (beginning/end) position of the digit from 0 to 9 then press the right key ("S") else press the left key ("K")". The rules are presented in Fig. 1. The stimulus was presented until the participant responded or until 50 s had elapsed, and then we provided the correct/incorrect feedback.

The performance in Phase 2, namely the number of trials required for rule finding, served as the dependent measure indicating difficulty in rule finding (Heaton & Pendleton, 1981; Schwartz, 1982; Verguts, De-Boeck, & Maris, 1999). Because the results were essentially the same for the number of trials needed to find the solution as for the time taken until the solution was found, we decided to report only the number of trials.

3. General method–Experiments 1–3

3.1. Participants

All the participants were undergraduate students from Ben-Gurion University of the Negev from the departments of Psychology or Behavioral Sciences (Experiments 1) who participated for partial course credit, or from Engineering departments (Experiments 2–3) who participated for a payment of 20 NIS (roughly 4 EURO) per 20–30 min session. They were assigned to the different groups in each experiment according to the order in which they entered the experiment.

3.2. Apparatus and stimuli

All testing was performed using desktop computers with 17" monitors, which were controlled by software written in E-Prime (Schneider, Eschman, & Zuccolotto, 2002a, 2002b). Each one of the three experiments involved two rules. Rule 1 and Rule 2 applied to the same stimuli and responses: The stimuli were composed of a letter (A, B, Y, Z) and a number (1, 2, 8, 9) (e.g., "A8"), typed in Courier-New at 25 dots per inch, and presented inside a 3×2 cm frame in the middle of the screen. Participants had two optional answers for each stimulus, pressing the keys – the left key ("S") and the right key ("K"). Rule 3 involved a circle and a vertical line. The circle had four different border widths (1.50, 1.00, .50, and .25 mm), and the vertical line, had four different lengths (15, 12, 6, and 3 mm). Both the circle and the line could appear in different colors (Black, Green, and Blue). The circle and line were presented inside a 3×2 cm frame in the middle of the screen. Rules 1–3 are presented in Fig. 1.

3.3. Procedure

Participants were tested individually in a quiet room and received instructions before performing each task. Each trial consisted of the presentation of a test stimulus until the participant responded or until 50 s had elapsed, followed by correct/incorrect feedback. The critical manipulation presumably involved a change in mindset. All the experiments included a group who applied an instructed rule (Instructed Rule) during Phase 1. They were compared with participants who did not go through Phase 1 (Baseline) or participants for whom Phase 1 involved rule finding (Rule Finding) with the same rule as the Instructed Rule group. Rule finding was based on the correct/incorrect

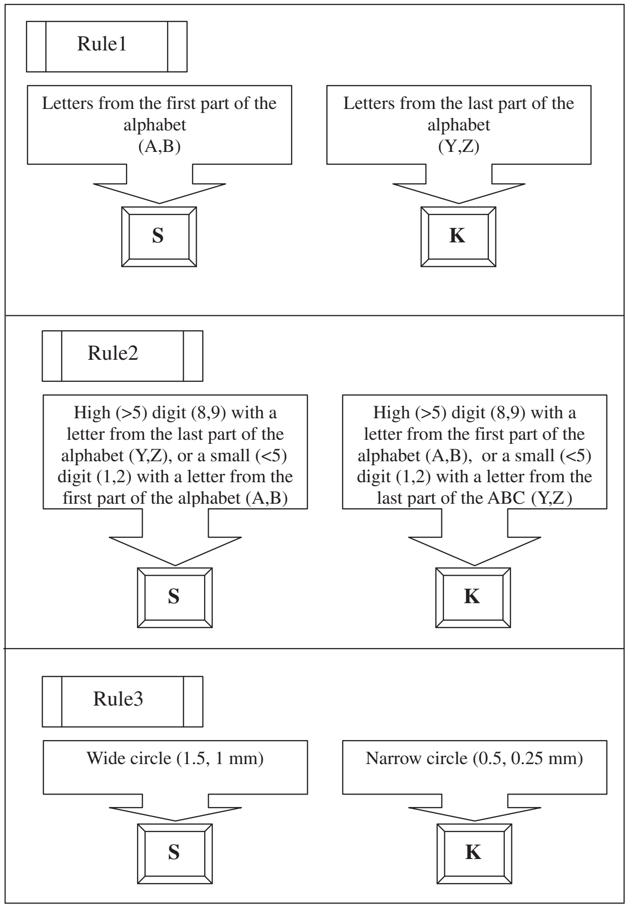

Fig. 1. Rules used in the experiments.

feedback provided by the computer program. Phase 2 involved rule finding of a different rule and was identical for all the participants. We defined successful rule finding by a criterion of a 12 consecutive correct responses. We verified this criterion by later asking for a verbal report of the rules. A failure to find a rule was defined as failing to meet the success criterion within 280 trials. The performance in Phase 2, namely the number of trials required for rule finding (excluding the criterion trials), served as the dependent measure. Importantly, Phase 1 activity involved a different rule than Phase 2 activity and was intended to establish the relevant mindset (either a mindset of instructed rule or a mindset involving the hypothetical activation of the processes involved in rule finding). The transition to Phase 2 was notified by a break in which the experimenter gave instructions for rule finding and emphasized that Phase 2 rule is different from Phase 1 rule. The experimenter also made sure that the participants understood the instructions. The experimental design is discussed in detail for each experiment below.

4. Experiment 1

The main goal of this experiment was to provide a preliminary test of our hypothesis. The experiment involved five groups who differed in the activity they were engaged in during Phase 1. They included Instructed Rule groups, a Baseline group and Rule Finding groups. Another goal was to differentiate the effect that was due to applying an instructed rule from influences that are due to short term past experience with the stimuli, since the latter serve as a common explanation for situational impairments in rule finding and in problem solving (e.g., Berg, 1948; Langer, 1989). The Instructed Rule and Rule Finding groups were formed according to a 2×2 factorial design in which one independent variable was related to the mindset (Phase 1 Activity: Instructed Rule vs. Rule finding), and the other independent variable was related to the amount of past experience with the stimuli: The Number of Application Trials (12 vs. 100). These trials were the number of executed trials in the Instructed Rule groups. In the Rule Finding groups these were the number of consecutive trials executed after the criterion for successful rule finding was reached.

In Phase 1 of the experiment, we used a simple unidimensional rule (Rule 1) and in Phase 2 we used a more complex two-dimensional rule (Rule 2). This way we controlled the possibility that participants would consider the Phase 2 rule in Phase 1 of the experiment and consequently Phase 2 would involve rule retrieval instead of rule finding. The aforementioned structure of the rules addresses this problem since it is extremely unlikely that participants would consider a two-dimensional rule before considering a uni-dimensional rule. We note that this feature of the experimental design does not appear to have caused the results we report. This is because the detrimental effect of Instructed Rule was found in additional experiments, not reported here, in which we reversed the order of the rules used in the two phases of the experiment.

4.1. Method

4.1.1. Participants

Fifty participants were assigned to five groups, 10 in each group.

4.1.2. Procedure

Only four groups had an activity during Phase 1, while the Baseline group did nothing during this phase. Phase 1 involved either rule finding or applying an instructed rule (Rule 1), and either 12 consecutive correct responses (Few Applications group) or 100 consecutive correct responses (Many Applications group). All the five groups went through Phase 2, which ended after 12 consecutive correct responses. Phase 1 ended with a short break during which the participants received instructions for rule finding of a new rule (Rule 2) that differed from the Phase 1 rule.

4.1.3. Results and discussion

The means of the number of trials needed to find Phase 2 rule are presented in Fig. 2. We performed two analyses: The first analysis compared Phase 2 performance of each one of the four groups who went through Phase 1 to the Baseline group. For this analysis, we ran a series of planned contrasts using the pooled error term, based on a one-way Analysis of Variance (ANOVA) comparing all the five groups. In each comparison, one of the experimental groups was compared against the Baseline group.

Three of the four planned comparisons indicated a significant effect. These included the two groups with many application trials, $t(46) = 2.54, 1.95$, $p < .05$ (a result consistent with theories emphasizing short term past experience, (e.g., Berg, 1948; Luchins, 1942) and a third comparison, which involved the Instructed Rule-Few Trials group. This comparison showed that participants in the Instructed Rule-Few Trials group required more than twice the number of trials to find the Phase 2 rule as compared with the Baseline group, $t(46) = 2.41$, $p < .05$. The Rule Finding-Few Trials group did not differ significantly from Baseline.

The fact that the Rule Finding-Few Trials group performed at Baseline level suggests that rule finding is *not* improved by limited practice. It also indicates that participants did not benefit from the prior rule finding mindset compared to Baseline, but rather that applying an instructed rule established a mindset that was sub-optimal for subsequent rule finding. This point will be discussed at greater length below.

The results are also important in ruling out another potential explanation based on Schwartz (1982). This author found that a stereotyped response was developed and subsequent attempts to find an alternative response sequence were impaired following a procedure in which a specific response sequence was reinforced. He concluded that the critical factor is being given a reward leading participants concentrate on reward production. This cannot explain the present results because participants in the Rule Finding group received as many consecutive positive feedbacks

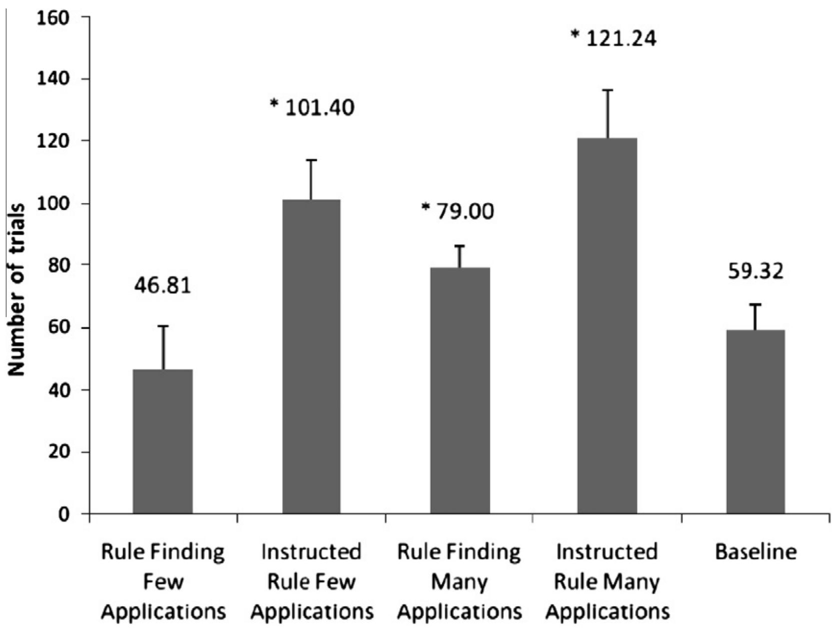

Fig. 2. Number of trials required for Phase 2 rule finding, Experiment 1. Error bars represent the standard error of the mean, * indicates a significant difference relative to baseline.

(which constitute the reward) as those who applied an instructed rule. It is also possible to claim that in the Rule Finding group, the participants received a reward for the process of rule finding itself. However, this should have reinforced further rule finding. Accordingly, we would expect an advantage for the Rule Finding group as compared with Baseline. The results of this experiment show that this was not the case.

In the next stage of the analysis, we ran a 2 $\times$ 2 ANOVA according to the independent variables Number of Application Trials (Few vs. Many) and Phase 1 Activity (Instructed Rule vs. Rule finding) on the results of four of the groups, excluding the Baseline group. This analysis revealed that both variables had independent influences on rule finding. Specifically, participants in the Rule Finding groups needed fewer trials to find the Phase 2 rule ($M = 62.90$, SD = 57.18) as compared to those who applied an instructed rule ($M = 111.32$, SD = 90.11), as indicated by the significant main effect of Phase 1 Activity, $F(1, 36) = 2.91$, $p < .05$. Another significant main effect was the effect of Number of Application Trials, ($F(1, 36) = 1.98$, $p < .05$), indicating that, as predicted, participants who applied Phase 1 rule fewer times (either after rule finding or in the Instructed Rule group) needed fewer trials to find Phase 2 rule ($M = 74.10$, SD = 62.72) as compared to the participants who applied Phase 1 rule many times (either after rule finding or in the Instructed Rule group) ($M = 100.12$, SD = 75.21). In this analysis, Phase 1 Activity represents a manipulation of the mindset and Number of Application Trials represents a manipulation related to the contribution of short term past experience with the stimuli. The non-significant two-way interaction suggests that, aside from the well documented influence of short term past experience, there is additional and independent influence of mindset. Note also that starting with rule finding does not immune one from the deleterious influences of applying an instructed rule. Specifically, the participants in the Rule Finding-Many Trials group began with rule finding but had to apply the rule they found for many times, which resulted in subsequent impairment in rule finding performance. This impairment due to the continuous application of a self generated rule was almost as serious as the application of an instructed rule.

5. Experiment 2

The goal of this experiment concerned the boundary conditions of the former findings. It appears that applying a rule 12 times was sufficient to cause drastic impairment in rule finding performance. In the present experiment, we examined the possibility that the mindset associated with Instructed Rule is established very quickly. The literature on task switching (Kiesel et al., 2010; Meiran, 2010; Monsell, 2003; Vandierendonck, Liefooghe, & Verbruggen, 2010, for review) discusses how mindsets associated with simple speeded cognitive tasks are established. Admittedly, the mindsets discussed in that literature are probably quite different than those discussed in relation to rule finding. Yet, it is possible that establishing mindsets follow similar regularities in these two domains. Of interest is the well established finding in task switching showing that mindsets are often fully established after a single execution of a task rule (Rogers & Monsell, 1995, for the first demonstration). Specifically, the results show that a task switch results in slowing in the trial immediately following the switch. However, performance improves immediately in the next trial and remains stable thereafter, suggesting that the execution of the first trial in the switched task was sufficient to establish the required mindset (Rogers & Monsell, 1995). Moreover, this literature also shows that a single execution of the switched task is not only sufficient to establish a mindset for that task but is also necessary. Specifically, if participants are told to switch tasks but are also told to avoid responding on a certain proportion of the trials (nogo trials), there is switching cost only in trials following a response (go trials) and this cost is eliminated in trials following nogo trials (Schuch & Koch, 2003, see Philipp, Jolicoeur, Falkenstein, & Koch, 2007, for review). This means that in order to establish a mindset one has to actually perform a task. Thus watching a task being executed by someone else would probably not induce the mindset.

In the present experiment, we drew on this analogy between mindsets of simple speeded tasks as studied using task switching and the mindsets related to rule finding. Specifically, we were interested to examine the possibility that, despite the very different nature of the mindsets involved, a single response made in an instructed rule mode would be sufficient to establish an instructed rule mindset and impair subsequent rule finding. In contrast, watching someone else applying the rule would not cause such an impairment. Thus, in this experiment we contrasted two groups with a Baseline group. In one group, the participants executed a single response applying an instructed rule (One-Trial Instructed Rule). In the other group, the participants watched how an instructed rule is executed but did not actually execute the rule themselves (Instruction Demonstration).

5.1. Method

5.1.1. Participants

Thirty undergraduate students were assigned to three groups, 10 in each group: Instruction Demonstration, in which Phase 1 involved one-trial demonstration by the experimenter; One-Trial Instructed Rule in which the participants executed one trial; and Baseline.

5.1.2. Procedure

In the One-Trial Instructed Rule group, the experimenter explicitly gave the Phase 1 rule (Rule 1) and asked participants to respond according to it. The experimenter explained to the participants that Phase 1 includes only one trial and that after a single response she will give them the instructions for Phase 2. The instructions and Phase 2 itself were similar to Phase 2 in Experiment 1.

In the Instruction Demonstration group, participants did not go through Phase 1 but when they received the instructions for rule finding (similar to Phase 2 in the previous experiment) they received the Phase 1 rule (Rule 1) as an example during the instructions. After explaining the task (finding a rule by thinking of possible rules, testing them according to the feedback and so on) they were told that "a rule could be..." and were given a description of Rule 1. They were also told that this is an example and that the rule they have to find is different from that example. The Baseline group was similar to that in Experiment 1.

5.1.3. Results and discussion

All of the participants found Phase 2 rule, but as indicated by the planed comparison (using the pooled error term), participants in the One-Trial Instructed Rule group required almost twice as many trials ($M = 71.98$, SD = 35.91) as the Baseline group ($M = 42.32$, SD = 30.12), $F(1, 27) = 6.72$, $p < .05$. Participants in the Instructions Demonstration group performed at a similar level ($M = 38.14$, SD = 28.18) to that of the Baseline group ($F(1, 27) < 1.05$, ns.).

The results of this experiment show that a single execution of an instructed rule can severely impair subsequent rule finding. Like the mindsets of simple speeded tasks, a single rule application seems to be both necessary and sufficient to establish a mindset associated with executing an instructed rule.

Aside from establishing the analogy between mindsets of simple speeded tasks as studied with task switching and rule finding, the present results also show that the mindset of instructed rule is relatively independent of the task's stimuli, since it exists even though participants in Phase 1 encountered only 1 of the 16 possible stimuli that were then used in Phase 2. This feature seems to contrast with the mindsets that have been discussed in task switching, which are arguably retrieved by the stimuli (Waszak, Hommel, & Allport, 2003). Nonetheless, while Waszak et al. showed a large contribution of stimulus repetition to set shifting difficulty, they also observed shifting difficulty albeit smaller in size in the absence of stimulus repetition. Thus, the task switching results show an impairment that is not entirely due to stimulus repetition.

This experiment also helps ruling out an alternative explanation suggested by one reviewer. According to this explanation, participants in the Instructed Rule groups of the previous experiment became bored during Phase 1 because applying a rule is not an engaging task. According to the alternative account, this fact caused them to become less engaged and hence less efficient in the subsequent rule finding of Phase 2 as compared with Baseline. We think that it is extremely unlikely that one would become bored by a single application of a rule. Thus, the fact that the results of Experiment 1 replicated with a single rule application trial during Phase 1 essentially rules out the boredom account.

6. Experiment 3

In the present experiment, we tried to push the mindset idea one step further and examined whether applying an instructed rule regarding one stimulus set would impair rule finding performance with a completely different stimulus set. If rule finding performance would be impaired even with a change in stimuli, this would suggest that the mindset represents the preparatory cognitive activity that *precedes* thinking and perception (Duncker, 1945). Importantly, the literature suggests that the change of stimuli between the phases should actually make the transition easier. The reason being that participants probably form a habit of applying a certain rule to a given set of stimuli so that the next encounter with *these stimuli* leads to the retrieval of the preceding rule, a fact which interferes with the ability to find a new rule. Such stimulus-based accounts have been supported both in problem solving (Berg, 1948; Kaplan & Simon, 1990; Knöblich et al., 2001; Langer, 1989) and in task switching, showing larger switch costs for repeated stimuli as compared with conditions involving a stimulus change (e.g., Waszak et al., 2003).

6.1. Method

6.1.1. Participants

Twenty-four participants were assigned to the Instructed Rule group and the Baseline group, 12 in each group.

6.1.2. Stimuli and rules

Phase 1 involved Rule 3 (with shape stimuli) and Phase 2 involved Rule 2 as in previous experiments (with letter–digit combinations).

6.1.3. Procedure

In the Instructed Rule group, participants explicitly received Rule 3 concerning circle and line and were required to apply it for 12 trials. Phase 2 was similar to previous experiments. Since the instructions for rule finding included mentioning the set of stimuli ("you should find a rule regarding digit–letter pairs") participants were obviously aware of the change in stimuli from Phase 1 that included circle–line pairs. The Baseline group was the same as in the previous experiments.

6.1.4. Results and discussion

As in the previous experiments, participants in the Instructed Rule group needed more than twice the number of trials as compared to the Baseline group, ($t(22) = 2.66$, $p < .05$) to find the Phase 2 rule. Specifically, the mean number of trials to find the rule in the Instructed Rule group was 111.47 (SD = 38.51), whereas the mean in the Baseline group was 55.20 (SD = 29.41). From this experiment, it is clear that the mindset created by applying an instructed rule can affect rule finding even when it is performed on completely different stimulus set (and rules), which further shows the critical role played by the preparatory activity, namely, the mindset in determining performance.

Taken together, the results from Experiments 2 and 3 imply that applying an instructed rule has quick and devastating effects on subsequent rule finding, independent of the stimulus set used during Phase 1.

7. General discussion – Experiments 1–3

So far we found interference to rule finding due to having previously performed a task requiring the application of an instructed rule. This interference was independent of past experience with the test stimuli.

Of particular interest is the fact that rule finding in Phase 2 did not benefit from previous rule finding in Phase 1. We already noted that this result shows that finding a rule in Phase 1 did not lead to a meaningful improvement in rule finding skill, in line with the idea that the mindset (rather than the skill) constituted the most important contribution to the performance differences that we observed. One reviewer suggested that this lack of difference may reflect insensitivity of the dependent measure. While we cannot fully rule out this possibility, we find it very unlikely for several reasons. One is that the task that we used in Phase 2 was sufficiently sensitive to detect the very substantial impairment that we observed in the Instructed Rule conditions in the three experiments. Still, one could argue that performance has reached floor and therefore became insensitive to detect improvements in ability. This floor account does not seem plausible because the performance level of the Baseline group in Experiment 1 ($M = 59.32$) was poorer than that in Experiment 2 ($M = 42.32$), suggesting that floor level has not been reached.

We additionally suggest that the best account of our results is based on two related premises. First, we suggest that maintaining the mindset of rule finding is effortful. Second, we suggest that the rule finding mindset takes long to (re)activate. Simple cost benefit analysis suggests that with these constraints, participants would keep the rule finding mindset active despite the associated effort as long as the chances are sufficiently high that it will be required soon. This would be especially true in situations associated with reasonably high rule finding rewards or costs which outweigh the cost (in effort) associated with keeping the mindset active. However, when the environment provides sufficiently clear signals that the rule finding mindset is unlikely to be needed (as in the Instructed Rule group) participants would choose to turn the rule finding mindset off. They would do so in order to avoid the effort associated with keeping the rule finding mindset active.

A second set of findings regards the scope and generality of the phenomenon (Experiments 2–3). The findings revealed that applying an instructed rule once was both necessary and sufficient to cause drastic impairment in subsequent rule finding. These results indicate that the establishment of the mindset associated with instructed rule was immediate, resembling the establishment of task sets associated with simple speeded tasks as studied with task switching (Rogers & Monsell, 1995; Schuch & Koch, 2003). We also found that applying an instructed rule regarding one stimulus set impaired rule finding on a quite different stimulus set.

Importantly, the drastic interference has been shown to be independent of recent past experience with the test stimuli (e.g., Luchins, 1942), which is one of the central explanations for failures in rule finding and problem solving. Moreover, this mindset is a result of an activity that has already ended and therefore is unlikely to reflect working memory load. In fact, if working memory was still loaded with information related to Phase 1 then one would expect rule finding to be *poorer* following rule finding as compared to applying an instructed rule. The reason being that rule finding is likely to involve working memory to a greater extent than applying an instructed rule. The fact that the trend in Experiment 1 was opposite rules out this alternative explanation.

Our results are consistent with Duncker's (1945) notion concerning the preparatory set that participants bring to the task at hand. Specifically, this set is a distinct type of mental preparation, supposedly manifested in a distinct brain state (Kounios et al., 2006). The set includes the specific processing resources that are activated as well as their task-appropriate tuning. Experiments 4–6 were run in order to gain further insight regarding the nature of that mindset.

8. Experiments 4–6

In their COVIS model, Ashby et al. (1998) identified three central processes in rule finding (through Rule Based Category Learning): feedback evaluation, rule generation, and switching attention between rules. In the following experiments, we examined which one of these three processes is adversely affected by a mindset associated with applying an instructed rule. We therefore tested whether the mindset effect transfers to tasks that do not involve rule finding but share critical components with it. The reasoning was that if rule finding involves the aforementioned three processes the prediction is that one or more of them would be impaired following the execution of an instructed rule. We therefore, manipulated mindset in Phase 1 of each experiment in a similar way to that used in the previous experiments. However, in contrast to these experiments, Phase 2 did not test rule finding. Rather, Phase 2 consisted of different paradigms, each presumably tapping a single component process that is arguably involved in rule finding according to the COVIS model. We therefore suggest that it is possible to test mindset influences on specific processes rather than at the level of the general task performance, as previously shown in the mindset literature (e.g., Galinsky & Kray, 2004). The reasoning here is that since we argue that mindset determines the configuration of process, its influence would be noticed at the relevant process level.

Feedback evaluation was tested by a tailored Post-Error Slowing paradigm (Experiment 4), rule generation was tested by a tailored Rule Fluency paradigm (Experiment 5), and attention switching between rules was tested by a tailored Task Switching paradigm (Experiment 6).

9. General method

9.1. Participants

Participants were either undergraduate students from Ben-Gurion University of the Negev, from the Engineering departments (Experiment 4), who participated for a payment of 20 NIS (~4 EURO) per 20–30 min session, or unpaid volunteers who were engineers between 25–35 years of age (Experiments 5–6). They were assigned to the groups in each experiment according to the order in which they entered the experiment.

9.2. Apparatus and stimuli

Testing was performed using either desktop computers with 17" monitors (Experiment 4), or a Lenovo N 500 laptop computer with a 15.4" monitor (Experiments 5–6). Software for all the experiments was written in E-Prime (Schneider et al., 2002a, 2002b). All of the experiments involved Rule 3 in Phase 1 of the experiment. Phase 2 involved Rule 1 in Experiment 4 and Rules 1 and 2 in Experiment 6. Importantly, by using Rule 3 in Phase 1 (which is based on line–circle stimuli) and Rules 1, 2 in Phase 2 (which are based on letter–digit stimuli), we made sure that we are testing an influence of a mindset that is independent of the past experience with the stimuli. Responses were similar to those in previous experiments ("S" (left) or "K" (right)) (Rules 1–3 are presented in Fig. 1).

9.3. Procedure

All the experiments involved two groups, with Phase 1 which was identical to that used in Experiment 3. One group was Instructed Rule and the other was Baseline. Like in Experiment 3, the participants who were asked to apply Rule 3 did so for 12 consecutive trials. As in the previous experiments, the participants did not receive any instructions regarding accuracy or speed during Phase 1. Rather they were simply asked to apply the instructed rule. Phase 2 involved a different task in each experiment. As in previous experiments, participants in the Instructed Rule group were notified that the experiment includes two phases and that the instructions for Phase 2 will be given after Phase 1 is completed. After completing Phase 1, an explicit brake was introduced and then the instructions for Phase 2 were given. The experimental design is discussed in detail below.

10. Experiment 4

In this experiment, we tested whether an instructed rule mindset would impair the process of feedback evaluation. In order to test feedback evaluation, we adopted in Phase 2 a speeded classification task that involved an equal emphasis on accuracy and speed. This created a constant need for monitoring to ensure that the subtle balance between these two conflicting requirements is kept. In this task, an error indicates that the balance has been violated and that adjustment in the speed-accuracy tradeoff is required. A behavioral index of this monitoring is the Post-Error Slowing effect (Rabbit, 1966; see Luce, 1986, for review). This effect shows that responses are slowed if they immediately follow an error relative to when they follow successful trials and that subsequently reaction-times (RTs) trend back toward the overall mean (Notebaert et al., 2009). The critical index is the RT difference between two types of trials: those following an error and those following successful responses. The predominant account of this effect is that the negative feedback results in a shift to a relatively conservative response selection strategy, supposedly indicating reactive adjustments in control (Laming, 1968). Of interest here is the fact that Post-Error Slowing is believed to involve the putative monitoring system in the dorsal anterior cingulate cortex (Botvinick, Braver, Carter, Barch, & Cohen, 2001). Regardless of the exact neurological mechanism, there is relative consensus that Post-Error Slowing indicates performance monitoring with greater slowing indicating more vigilance. Since feedback evaluation is a critical component of rule finding and rule finding is presumably impaired by an instructed rule mindset, we predicted that being in mindset of instructed rule would interfere with feedback evaluation. This means that in the Instructed Rule group, there would be less Post-Error Slowing as compared with the Baseline group. It is important to mention the fact that the present experiment is interesting in another respect. This is because it concerns an impairment found in a task involving applying an instructed rule rather than a task involving rule finding as in Experiments 1–3. Thus, a support for our prediction would show that the impairment caused by applying an instructed rule spans to tasks other than rule finding as long as they share critical component processes with rule finding.

10.1. Method

10.1.1. Participants

Fourteen undergraduate students were assigned to one of two groups, 7 in each group: Instructed Rule and Baseline.

10.1.2. Procedure

Phase 1 involved applying the instructed Rule 3 in the Instructed Rule group for 12 trials. In Phase 2 of the experiment, all the participants were asked to apply Rule 1 for 200 trials as quickly and accurately as possible.

10.1.3. Results and discussion

Post-Error Slowing is measured by comparing RT in trials following errors to trials following correct responses. The individual mean RTs were submitted to a 2-way ANOVA according to the independent variables Group and Condition. The results of this analysis revealed a dramatic decrease in Post-Error Slowing after applying an instructed rule as seen in a significant interaction between Group and Condition, $F(1, 12) = 15.50$, $p < .05$, supporting our hypothesis. Specifically, RT following an error vs. a correct response was 478 vs. 456 ms in the Instructed Rule group (indicating non-significant Post-Error Slowing of 22 ms) as compared to 568 vs. 466 ms in the Baseline group (indicating significant Post-Error Slowing of 102 ms, $p < .05$, see Fig. 3). Therefore, the general finding of slowing after recognizing an error (observed in the Baseline group) was nearly eliminated in the Instructed Rule group. Note the fact that the mean RT for trials following correct responses (which were the vast majority of the trials) was almost identical in the two groups, suggesting that applying an instructed rule did not result in a general shift of speed-accuracy tradeoff in favor of speed. This near equivalence of the groups in trials following correct responses (which were

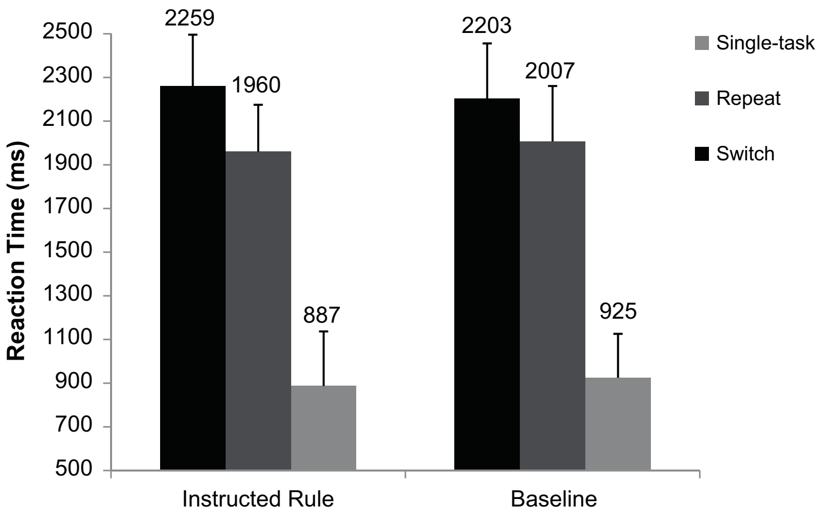

Fig. 3. Phase 2 rule application reaction-time (ms). Error bars represent the standard error of the mean, * indicates a significant difference between post-error and post-correct.

the vast majority of the trials) rules out the alternative explanation that the participants in the Instructed Rule group wanted to be done with the experiment due to boredom or lesser motivation.

This experiment indicates that applying an instructed rule (presumably establishing a mindset) drastically reduces Post-Error Slowing. Since Post-Error Slowing is widely interpreted as evidence for feedback monitoring, these results indicate that being in a mindset of instructed rule impairs feedback evaluation. An alternative explanation known in the post-error slowing literature is that the effect reflects the importance given to errors with less importance leading to smaller post-error slowing (Hajcak, Moser, Yeung, & Simons, 2005). Accordingly, one may argue that participants in the Instructed Rule group gave lesser importance to errors. This explanation can be ruled out since no difference was found in the error proportion between the groups in Phase 2 (M = .08; SD = .02, M = .12; SD = .03, for Instructed Rule and Baseline, respectively). If anything, the trend implies fewer errors in the Instructed Rule group which is opposite to what one would predict based on the aforementioned alternative account.

11. Experiment 5

The second process that according to COVIS (Ashby et al., 1998) underlies rule finding is rule generation. Generation abilities are commonly tested by open-ended fluency tasks (Guilford, 1967; Torrance, 1966). Fluency is a measure of production and refers to the number of non-redundant ideas, or products that are being generated (Amabile, 1983; Guilford, 1967; Paulus & Nijstad, 2003; Sternberg & Lubart, 1999; Torrance, 1966). Since rule generation is a process critical for rule finding, we predicted that this process would be impaired by an instructed rule mindset. Therefore we designed a novel Rule Fluency task to be used in Phase 2. In this task, the participants were asked to generate as many hypotheses concerning possible rules as they could in a given period of time. Admittedly, this kind of Rule Fluency task includes both rule generation and rule switching. Partly for that reason, we also tested switching in purer form in the next experiment.

11.1. Method

11.1.1. Participants

Twenty engineers who volunteered to participate in the experiment were assigned to one of two groups, 10 in each group: Instructed Rule and Baseline.

11.1.2. Procedure

Phase 1 was similar to that in Experiment 4. In Phase 2, both groups received all the possible letter–digit combinations of four letters (A, B, Y, Z) and four digits (1, 2, 8, 9). They were asked to think of as many rules as possible that could classify the entire stimulus set into two groups. Participants sat in front of a computer which continuously presented the entire set of letter–digit combinations and was programmed to collect RTs. The participants were instructed to press the space bar every time they generated a new rule and to write down a word that would later remind them of that rule. After every key-press the screen color changed, indicating that the key-press was recorded. Participants pressed on the “E” key when they could no longer generate rules. When the experiment ended, participants gave detailed description of the rules that corresponded to the relevant code word written during the experiment.

11.1.3. Results and discussion

We performed an analysis on the number of non-redundant rules that were generated. The Instructed Rule group generated a significantly smaller number of rules (M = 9.02, SD = 2.17) as compared to the Baseline group (M = 13.75, SD = 2.92), $t(18) = 2.13$, $p < .05$.

While the results support the prediction, they could also be explained as reflecting motivation differences

Please cite this article in press as: ErEl, H., & Meiran, N. Mindset changes lead to drastic impairments in rule finding. *Cognition* (2011), doi:10.1016/j.cognition.2011.01.002

between the groups. Specifically, it could be argued that the Instructed Rule groups were less motivated to continue generating rules during Phase 2 of the experiment as compared to Baseline. In order to deal with this alternative explanation, we analyzed the mean RT per each generated rule. According to the mindset prediction, participants in the Instructed Rule group generated less rules than the Baseline group because their ability to generate rules was temporarily compromised. This leads to the prediction that they would also be slower in generating the rules. A motivation account does not predict such slowing. The analysis of RTs was carried out on the first four generated rules, because this was the number of rules generated by the poorest participant, and analyzing additional rules had to exclude some participants. The analysis revealed that the Instructed Rule group were numerically slower to generate three of the four rules as compared to Baseline, Rule 1: $M = 34.70$ vs. 25.22 s, Rule 3: 22.00 vs. 18.17 s, Rule 4: 36.18 vs. 18.54 s, respectively. In Rule 2 the trend reversed: $M = 12.59$ vs. 17.16 s, respectively. While these trends did not approach significance due to huge variability, they are in the predicted direction according to our account. We also performed a qualitative analysis of the rules. This analysis revealed that most of the participants in both groups first generated uni-dimensional rules and only then started generating two-dimensional rules. We did not find any group differences in this trend. Of interest are the rules which did not consider the stimuli as representing digits and letters, which were the salient dimension. About one half the participants in each group generated a rule which considered the shape of the stimuli irrespective of their digit/letter identity (five in Baseline and four in Instructed Rule). Such rules were generated only in a relative late stage, supporting the interpretation that these are difficult to generate rules. Interestingly, they were generated in an earlier position in the Baseline group ($M = 9.25$) compared to the Instructed Rule group ($M = 12.5$), $t(7) = 1.79$, $p < 0.11$, by a one sided test, implying being able to observe non-salient stimulus dimensions tended to be relatively difficult after applying an instructed rule.

While we acknowledge the fact that the motivation account cannot be entirely ruled out in this experiment, this account fails to provide a unitary explanation for the entire set of experiments. Specifically, it is difficult to see how the motivation account could deal with the results of Experiments 1–3, especially Experiment 3. This experiment involved an identical manipulation and the results showed that the Instructed Rule group worked for a longer period of time during Phase 2 and received more negative feedbacks than the Baseline group.

12. Experiment 6

The last process underlining rule finding according to COVIS (Ashby et al., 1998) is attention switching between rules. This kind of attention switching was widely investigated by the task switching paradigm (for review see Kiesel et al., 2010; Meiran, 2010; Monsell, 2003; Vandierendonck et al., 2010). Of interest here are two performance indices that are computed by comparing three experimental conditions. In experimental blocks involving task switching there are two types of trials. Some trials involve task switching because the task in these trials is different from the task that was required in the immediately preceding trial. These are *switch trials*. Other trials involve an immediate task repetition. These are *repeat trials*. In addition, experiments often involve blocks in which only one task is required and there is no task switching. These are *single-task trials*. The two aforementioned performance indexes are defined by these three conditions: switch, repeat and single-task. The first index is *switching cost*, defined as the decrement in performance in switch trials relative to repeat trials. The second index is *mixing cost*, defined as the decrement in performance in repeat trials as compared to single-task trials.

According to current theorizing, switching cost reflects the actual switch of attention between task rules. In contrast, mixing cost is due to the maintenance of all the potentially relevant task rules in an active state in experimental blocks involving task switching in order to maintain readiness for switching (see Fagot, 1994; Kray & Lindenberger, 2000; Los, 1996; see Rubin & Meiran, 2005, for review). Specifically, in the task switching literature, there is a widespread agreement that the adoption of task sets is the major reason for the switching cost. For example, Rogers and Monsell (1995, see also Mayr & Kliegl, 2000) suggest that switching cost reflects the time taken to load a new task set prior to task execution. Allport, Styles, and Hsieh (1994, see also Sohn & Anderson, 2001; Yeung & Monsell, 2003) argue that switching cost results from the inertia of the previously adopted task set, which interferes with current processing. According to Allport and Wylie (2000) and Waszak et al. (2003), switching cost results from the binding of the task set with the target stimuli, which results in difficulty in applying another task set to these stimuli. Meiran (1996, 2000), and Meiran, Chorev, and Sapir (2000) suggested a hybrid approach that incorporates both of these factors. Regardless of the differences in the exact mechanism, the different approaches agree that an increased switch cost reflects poorer ability to switch attention between task rules. We therefore predicted that an instructed rule mindset would result in increased switching costs. However we did not make a similar prediction concerning mixing cost since maintaining readiness for a switch by keeping known information constantly activated is *not* among the processes responsible for explicit category learning according to COVIS (Ashby et al., 1998).

12.1. Method

12.1.1. Participants

Thirty engineers who volunteered to take part in this experiment were assigned to one of two groups, 15 in each group: Instructed Rule and Baseline.

12.1.2. Procedure

Phase 1 was similar to that in Experiments 3–5. In Phase 2, both groups received a task switching block followed by a block in which they applied only one task rule (single-task). In the task switching block, participants were required to switch between application of Rule 1 and application of Rule 2 for 70 trials. On half the trials, participants had to switch between the rules (switch trials) and on the other half, participants had to repeat the rule from the preceding trial (repeat trials). Switch and repeat trials were assigned randomly. The rule was indicated by task cues that flanked the target stimulus. For Rule 1, the task cue consisted of the Hebrew words Beginning/End, and for Rule 2 the task cue consisted of the Hebrew words for Congruent/Incongruent. The right/left position of the cue words indicted the right/left position of the corresponding response key. For example, if the word "Beginning" was on the right, this reminded the participants that the right key is used to indicate "Beginning". Participants were told to perform as quickly and accurately as possible.

On the single-task block which followed after a short brake, participants applied only one task rule for 35 trials. Each trial consisted of the stimulus and code words on his sides resembling the rule to be performed. The identity of the task rule for the single-task block was counterbalanced across participants, so that half of the participants received Rule 1 and the other half received Rule 2. Participants were told to respond as quickly and accurately as possible.

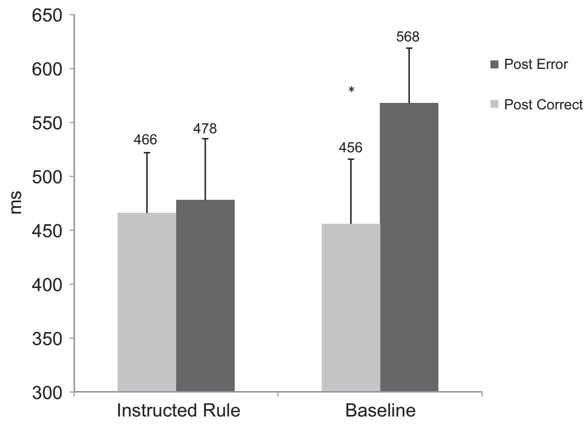

Fig. 4. Phase 2 reaction-times (ms). Switching cost is the difference in reaction-time between repeat and switch trials. Mixing cost is the difference in reaction-time between repeat and single-task trials. Error bars represent the standard error of the mean.

12.2. Results and discussion

12.2.1. RT

We analyzed switching costs and mixing costs separately. For each cost, we began with analyzing the specified planned contrast separately in each group, to show that the cost was present to begin with. Once this was demonstrated, we conducted another planned comparison which was the interaction contrast between Group and the contrast representing the relevant cost. This interaction contrast tested whether the cost differed between the groups (mindset influence).

12.2.2. Switching cost

The analysis revealed that switching cost (the switch vs. repeat planned contrast) was observed in both groups, $t(10) = 5.14, 4.45, p < .05$, for Instructed Rule and Baseline, respectively. Importantly, this switching cost was larger in the Instructed Rule group (299 ms) than in Baseline (196 ms) as indicated by the significant planned interaction contrast between Group (Instructed Rule/Baseline) and the switching cost contrast (switch vs. repeat), $F(1, 28) = 4.93, p < .05$, (see Fig. 4). Therefore, these results show that applying an instructed rule created interference in the ability to switch attention between classification rules, as indicated by the increased switching costs.

We also performed a group main effect analysis on the results of the first block in which the participants switched between tasks. The motivation behind this analysis was that the boredom account mentioned beforehand according to which participants in the Instructed Rule group get bored and thus react quickly during Phase 2 in order to be done with the experiment. The analysis revealed that the groups mean RTs did not differ significantly and were almost identical ($M = 2110$, SD = 648 ms, $M = 2105$, SD = 687 ms, for Instructed Rule and Baseline, respectively). This result together with the results of Experiment 2 and the fact that in Experiment 4 the instructed rule manipulation influenced trials following errors and did not influence trials following correct responses essentially rules out the boredom explanation.

12.2.3. Mixing cost

The analysis revealed that mixing cost (the repeat vs. single-task planned contrast) was observed in both groups, $t(10) = 9.56, 8.45, p < .01$, for Instructed Rule and Baseline, respectively. However, no significant difference was found between the groups (mixing cost was 1073 vs. 1082 ms, for Instructed Rule and Baseline, respectively) as indicated by the non-significant planned interaction contrast. These results show that applying an instructed rule does not influence the process responsible for maintaining the task rules in an active state in conditions involving task switching.

12.2.4. Errors

In general participants performed very few errors. No significant differences were found between the groups**.**

13. General discussion – Experiments 4–6

Our results show that all the three component processes that are involved in category learning according to COVIS (Ashby et al., 1998) were impaired in the Instructed Rule group relative to Baseline. Specifically, applying the instructed rule resulted in smaller Post-Error Slowing, fewer generated rules and enlarged switching cost. Since we showed that a manipulation causing drastic impairment in rule finding performance also impaired the three components postulated by COVIS, our results provide an important support for this theory.

Moreover, these results support the notion that the mindset effects found in Experiments 1–3 were mediated by influences on the specific configuration of processing resources and their tuning. In addition, the results of Experiment 6 show dissociation between a process which is shared by rule finding (indexed by switching cost) and a process which is not (indexed by mixing cost).

Admittedly, the Rule Fluency task used in Experiment 5 involved a switching component because when generating a new possible rule, participants had to stop considering the previous rule they had just generated. One way to show that fluency was impaired, and not only attention switching, is to compare the effect sizes associated with the performance decrement in Experiments 5 and 6. We chose to employ meta analytic procedures (Rosenthal, 1991) because they enabled us to compare effect sizes irrespective of the statistical analyses and the experimental measures that were used in the two experiments (see Rosenthal, 1991). In Experiment 5 (presumably involving both fluency and switching), group membership correlated $r_{pb} = .71$ with performance, while in Experiment 6 (switching alone) it only correlated $r_{pb} = .36$. This difference in effect size suggests that fluency was also affected by the instructed rule manipulation. Statistical comparison of these two point-biserial correlations reached one sided significance ($t(48) = 1.96$, $p = .028$). We note that this is a highly conservative analysis because the two abilities most likely correlate positively. This implies that the added explained variance in Experiment 5 (relative to Experiment 6), which is roughly what the correlation-difference indicates, is only a portion of the variance that is due to fluent rule generation. Therefore, these results suggest that the fluency component of rule finding was also influenced by prior application of an instructed rule.

The findings of Experiments 4–6 have another important implication that refers to the generality of the results from Experiments 1–3. In Experiment 3, we demonstrated that applying an instructed rule affects rule finding when it is performed on a completely different stimulus set. The results of Experiments 4–6 provide additional support for this hypothesis since all the three experiments involved a different set of stimuli in Phase 1 and Phase 2. They also extend the conclusions because the detrimental influences associated with applying an instructed rule during Phase 1 were observed in Phase 2 in tasks other than rule finding, including tasks associated with applying an instructed rule as found in Experiments 4 and 6. We address this seeming paradox below.

14. General discussion

Rule finding plays a crucial role in a variety of high order cognitive processes such as categorization, problem solving, decision making, creative thinking, dealing with novelty, and so on (Frensch & Sternberg, 1989; Hesketh, 1997; Sternberg, 1996; Sternberg & Frensch, 1992). This ability has been investigated from several perspectives over the years (Berg, 1948; Ollinger, Jones, & Knöblich, 2008). The idea that rule finding can be influenced by a general mindset, which is relatively independent of task features was introduced in the 1940s (Duncker, 1945; Woodworth, 1938) but was hardly studied since. Recently, this phenomenon received attention through studies which demonstrated a robust mindset influence on problem solving (Galinsky & Kray, 2004; Kounios et al., 2006, 2008).

In the present work, we revealed an immediate and drastic influence of applying an instructed rule on subsequent rule finding, even when rule finding involved a different stimulus set. Second, we showed that applying an instructed rule interfered with each one of the three processes composing rule finding according to COVIS (Ashby et al., 1998), including feedback evaluation, rule generation and attention switching between rules. Because the processes were evaluated in tasks other than rule finding, the results suggest that rule finding relies on mindset factors rather than specific task factors only. Taken together, the present findings imply that the processes related to rule finding (or rule finding mindset) can be "turned off" when not required. We suggest that participants are motivated to turn off the rule finding mindset because keeping it active is effort consuming. When later activity requires rule finding, the processes required for optimal rule finding performance need to be reactivated. We suggest that because the reactivation of the mindset needed for rule finding is effortful and takes time, the end result is an (at least initial) impairment in rule finding performance. In our experiments, the activity signaling that rule finding is not required was based on establishing an instructed rule mindset and by the fact that participants received the Phase 2 instructions (for rule finding) only after Phase 1 ended. Thus, the participants were unlikely to anticipate that rule finding will become relevant later on. To help explain our account we rely on an everyday life analogy. Let us say you are working on your computer. After it is turned on, starting any application is made easily and quickly. For that reason, as long as the computer might be needed it is kept on. After a while you need to leave your office or home for shopping. This signals that the computer is not needed in the near future and can be turned off. After turning off the computer, your co-author phones you, telling you that the action letter for your paper is now in your email and that your immediate reaction is needed. In this case, it will take you considerable time to read the action letter because doing so requires you to start the computer.

The main contribution of this work as we see it is in showing that *failure* in rule finding is not only due to poor ability as studied using individual differences or past experience with the test stimuli, a factor that has been emphasized in most of the previous work (Langer, 1989; Lewin, 1936; Luchins, 1942). The concepts of fixedness, functional fixedness, the Einstellung effect, mindlessness and so on, all refer to influences of some form of past experience on rule finding. This literature relies on the idea that failure occurs due to attending to a specific dimension that was emphasized by past experience (e.g., Berg, 1948; Langer, 1989). Moreover the literature mostly considers the end outcome, which is task performance (see Galinsky & Kray, 2004). In this study we provide indication that poor rule finding performance is mediated by the component processes that make the mindset. Accordingly, our results do not only indicate that rule finding depends on mindsets, but also go one step further in specifying the nature of the harmful mindset.

Because the mindset is the configuration of activated processes, when it is turned off, this would impact performance in any task that involves one or more of these processes. This is true even if this task is very similar to the task used to create the instructed rule mindset.

Specifically, when instructing the participants of the rule to execute in Phase 1, we made no mention of speed or accuracy and there was no requirement to switch tasks, thus making monitoring and switching unnecessary. In contrast, the instructed rule in Phase 2 of Experiment 4 required participants to maintain a subtle balance between speed and accuracy, thus forcing them to monitor their speed-accuracy tradeoff ration. Similarly, the instructed rules used in Phase 2 of Experiment 6 required task switching, thus involving the processes of rule switching.

An intriguing possibility is that some studies which examined how *recent* past experience with the test's stimuli influences rule finding and problem solving have actually involved mindset. Take, for example, Langer's (1989) "first encounter" manipulation. In this paradigm, a problem solving context is presented in an absolute manner (e.g., "this is an eraser"), or in a probabilistic manner ("this could be an eraser"). According to Langer (1989) the presentation of the main or salient dimension of the stimulus in absolute terms results is future commitment to that *specific* dimension. However, it is possible that this mode of presentation creates a mindset that included a tendency to notice only the main dimension of *any* stimulus.

Admittedly, we cannot rule out the possibility that the mindset established by applying an instructed rule was related to the test's stimuli to some extent since even when the stimuli and tasks changed, the overall testing environment remained unchanged. Specifically, in relation to Phase 1, Phase 2 was carried out in the same testing room, involved pressing keys in front of a computer, and involved simple visual, easy-to-name stimuli. Moreover both phases involved a logical rule which could be easily verbalized and had a clear relation to feedback. Thus, it remains possible that this mindset was tied to some abstract representation of the testing environment or general settings of the experiment. In any event, this kind of mindset is by far more general and more abstract than that discussed by previous theories that emphasized past experience with stimuli.

This study also leaves some important open questions such as how long does it take for the rule finding ability to turn back on? While a detailed answer to this question awaits future studies, some preliminary statements can already be made based on the current results. Specifically, participants in the Instructed Rule group took about 10 min to find the rule in Phase 2, suggesting that it takes at least this amount of time to re-engage the rule finding mindset. A similar estimate is derived in Experiments 4 and 6, which enable to test post-error slowing and switching cost in different stages of Phase 2. We did not observe a change in these indices in the course of Phase 2 which lasted approximately 7 min.

15. Conclusion

In conclusion, this work suggests that a mindset created by a former activity of applying an instructed rule drastically impairs subsequent rule finding performance. This mindset is relatively task independent, easily established and its influence is carried beyond the time period during which it is relevant.

Acknowledgements

We wish to thank three anonymous reviewers for their helpful comments.

This research was funded, in part, by a research grant to the second author from Israel Science Foundation.

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Please cite this article in press as: ErEl, H., & Meiran, N. Mindset changes lead to drastic impairments in rule finding. *Cognition* (2011), doi:10.1016/j.cognition.2011.01.002