Firing the Executive: When an Analytic Approach to Problem Solving Helps and Hurts

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Abstract:

There is a general assumption that a more controlled or more focused attentional state is beneficial for most cognitive tasks. However, there has been a growing realization that creative problem solving tasks, such as the Remote Associates Task (RAT), may benefit from a less controlled solution approach. To test this hypothesis, in a 2x2 design, we manipulated whether solvers were given the RAT before or after an implicit learning task. We also varied whether they were told to "use their gut" as part of either initial task. The results suggest that a less analytic approach engendered by a "use your gut" instruction benefits performance on the RAT for monolingual solvers. The same benefit was not found for bilingual speakers suggesting that more controlled solution processes may be needed when speakers with multiple lexicons perform this task, which relies heavily on accessing common phrases in a particular language.

Keywords:

intuition, creativity, bilingual

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Introduction

There is a general assumption that a more controlled or more focused attentional state is beneficial for most cognitive tasks. However, creative problem solving is one kind of task that may benefit from a less controlled approach (Wiley & Jarosz, 2012). Creative problem solving is distinctive in that successful solution generally requires a novel representation of the problem, or an original combination of diverse and remote associations in memory, which an overly analytic or focused approach may impede. If a solver is too focused during solution attempts, then they may only consider the most dominant or usual solution paths. Attempting to control solution progress via analytic or incremental approaches could also make the consideration of remote associations or novel solutions unlikely. Consistent with this hypothesis, studies have found that solvers with less working memory capacity, who possess less of an ability to control their own attention, can actually be more flexible creative problem solvers than participants with superior executive functioning (Ansburg & Hill, 2003; Beilock & DeCaro, 2007; Kim, Hasher, & Zacks, 2007). Similarly, creative problem solving performance seems to benefit when solvers are put in contexts that disrupt their ability to engage in more focused or controlled processing. For example, it has been suggested that positive affect broadens the scope of attention, which in turn improves creative problem solving (Rowe, Hirsh, & Anderson, 2007; Subramaniam, Kounios, Parrish, & Jung-Beeman, 2008), and that working at a nonoptimal time of the day can improve performance on insight puzzles (Wieth & Zacks, 2011). Similarly, biofeedback intended to induce a passive mental state (by increasing alpha wave activity) has also been shown to improve creative performance (Haarmann, George, Smaliy, & Dien, 2012). Moreover, moderate intoxication from alcohol at once decreases working memory capacity while it also improves creative problem solving (Jarosz, Colflesh, & Wiley, 2012). Taken together, these various results converge toward the suggestion that less cognitive control or less focused attention may actually facilitate creative problem solving by engendering a less analytic approach to solution.

One example of a creative problem solving task that seems to benefit from a less-controlled approach is the Remote Associates Task (RAT; Mednick, 1962). In this task, participants are given a set of three words (*eight, skate, stick*) and asked to find a fourth word that forms a compound phrase with the other three (*figure*). Success on this task is contingent upon the activation of weak semantic associations in memory (Bowden & Beeman, 2003; Mednick, 1962; Smith & Blankenship, 1991; Wiley, 1998). The goal of the present study was to test whether manipulating the nature of the solution approach adopted by individuals would alter performance on the RAT.

Manipulating Solution Approach

A main goal of the present study was to encourage a more passive, diffuse, or less analytic solution approach among solvers of the RAT. For most cognitive tasks, particularly those with an explicit goal or purpose, it is natural for people to attempt to control or focus their attention, as this generally aids intentional, systematic, or analytic processing (Engle, 2002; Wiley & Jarosz, 2012). However, performance on implicit learning tasks is thought to benefit from more incidental and passive processing of information (DeCaro, Thomas, & Beilock, 2008; Knowlton, Ramus, & Squire, 1992; Reber, 1976; 1993). Thus, this study had solvers perform an implicit learning task before the RAT which was intended to engender a less controlled, less focused, and less analytic approach to problem solving, and as a result should improve performance on a creative problem solving task.

One prominent paradigm for studying implicit learning is the artificial grammar task (Reber, 1976). This task has 3 critical features – 1) participants are incidentally exposed to grammatical letter strings under the guise of a short-term memory task, 2) they are then given a surprise test where they must identify strings conforming to that grammar, and 3) they are told to use their gut to make these decisions. Traditionally, results demonstrate that participants who learn rules implicitly are able to identify new examples of grammatical strings at above chance levels, while participants who are directed to look for rules explicitly do not do as well (Reber, 1976).

It was predicted that performing an implicit learning task before the RAT should improve creative problem solving performance compared to not performing an implicit learning task before the RAT. There could be two possible explanations for such a result. The first is that engaging in implicit recognition of patterns may prime a less-controlled, intuitive solution approach versus an analytic or deliberative approach. However, an intriguing alternate possibility is that the simple "use your gut" instruction that is typically part of this paradigm may itself be sufficient to affect performance on the RAT. To test this, the presence of a "use your gut" instruction was also manipulated on the initial RAT task.

Methods

Participants

One hundred and fifty-three monolingual English-speaking undergraduate students enrolled in Introduction to Psychology participated in this experiment for course credit as part of the subject pool at the University of Illinois at Chicago. Monolingual solvers were the target sample due to the consideration that performance on the RAT relies heavily on the ability to access common phrases in a specific language (English). In addition, 141 early bilingual or non-native English speakers from the same pool were also run through this study. Because these participants' solution processes may differ fundamentally from those of monolinguals, the two groups were analyzed separately first and then compared.

Linguistic status was determined via self-report questionnaire. A first question asked participants to report if they were a native English speaker. A second question asked participants to report if they considered themselves to be monolingual or bilingual (or multilingual). Then participants were asked to list all languages that they spoke, in order of fluency, including English, at what age they began speaking them, and how fluent they were in each on a scale from 1 – 10 (1 meaning not fluent, 10 being very fluent). The monolingual native English sample was comprised of people who reported being monolingual and spoke English as their native language. The early bilingual/non-native English speaker sample was comprised of people who reported being bilingual/multilingual from birth, or reported being non-native English speakers. Age of fluency did not differ among conditions in the bilingual sample, $F < 1$. While all bilinguals in the sample spoke English, other languages varied greatly. The most commonly reported other languages in our subject pool include Spanish, Indian and Chinese dialects, as well as other Asian, Arabic, and Eastern European language groups (Cushen & Wiley, 2011). Both linguistic groups were around 55% female and averaged 19 years of age.

Materials

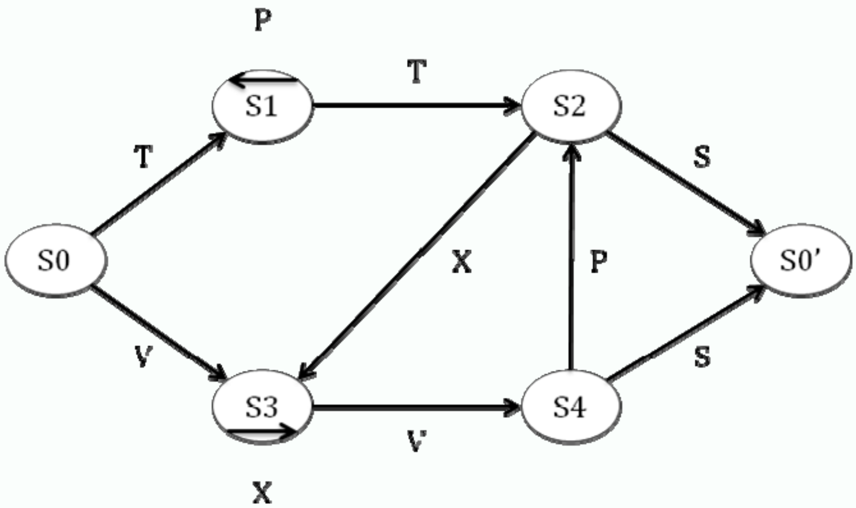
Artificial Grammar

The artificial grammar task was primarily based on Reber (1976) and a more recent version of the task (Kinder, Shanks, Cock, & Tunney, 2003). Two versions of this task were created: one that included a "use your gut" instruction and one that omitted this phrase.

In both versions of the task, a set of letter strings each consisting of three to eight letters was formed according to a finite state grammar shown in Table 1. The exact stimuli that were used are also included in Table 1. Participants were first run through a memory phase in which 15 strings were presented, then a test phase in which they determined whether a new set of strings followed the same underlying rules that governed the memory strings. At the start of the memory phase, participants were given the following instructions: *This is a simple memory experiment. You will see items made up of the letters PSTVX. They will run from three to eight letters in length. Your job will be to try to reproduce each item correctly from memory.* Each string was presented for three seconds (Kinder, et al., 2003). Next an answer blank appeared on the screen and participants needed to type back the string they had just seen. This was done for all 15 strings. After participants completed the memory phase, they were told: *The items you just learned were formed according to a complex set of rules. You will now see some new items.*

In the "use your gut" version of the task, these instructions ended with the line: *Just go with your "gut feeling" to decide whether each new item follows the same rules as the first* *set of items*. In the other version, these instructions ended with the line: *Your task is to decide whether each new item follows the same rules as the first set of items.* The test phase consisted of 22 grammatical and 22 nongrammatical strings in both versions, presented in the same randomized order for all participants. Responses were entered by pressing the '1' key if the string followed the underlying rule set or '2' if it did not.

Table 1
Schematic Diagram of the finite-state grammar used to generate stimuli (Reber, 1976) and Stimuli used in Artificial Grammar Task



15 Memory Strings	22 Grammatical Test Strings	22 Nongrammatical Test Strings
VXXXXXVS	TPTXVPS	TTX
TTXVS	VXVS	VVP
VXVPXXVS	TPPTXVPS	VXVPXTVS
VVS	TPPPPPTS	TPPPPXTS
TPPTS	TTXXXVS	VVPPVS
VXXVPS	TPTXXXVS	TTXVPTVS
TTXVPS	TPTXVS	VXXXXVP
TPTXXVS	TTXVPXVS	TTXVPX
VVPXVS	TPPTXXVS	TPTXVXSX
VVPXXVPS	VVPXXXVS	VSVTVX
TPPPTS	TPPPTXVS	VVXXPTP
VXXVS	TPPTXVS	VVPXXVPT
TTS	TPTS	TTXVP
VVPXXVS	TTXXXXVS	TPPTT
VVPS	VXXXXVS	VXVPPXVS
	VXXVPXVS	VTS
	VXXVPS	VVPXTS
	VXXXVS	VXXXPS
	TTXXVS	VXS
	VXVS	XVTSPX
	VXVPXVS	TTXVPX
	TPPTS	VVPX

Remote Associates Task

For each RAT item, participants were given a set of three cue words simultaneously, and their task was to identify a fourth word that would form *a common English phrase* with each of the words as in Wiley (1998). To familiarize solvers with the task, participants were given an example problem and five practice problems. The completed example problem (*washer, shopping, picture*) demonstrated that the solution word could be either the first or second word in the common phrase (*window washer, window shopping, picture window*). Participants then completed five practice problems after which they received the correct solution words. After completing the five practice items, participants solved the 20 target RAT problems. Participants had 30 seconds to solve each problem and were instructed to press the spacebar once they had the answer. After pressing the spacebar or after 30 seconds had elapsed, an answer blank appeared for 20 seconds in which participants needed to type in their response. Participants did not receive the correct solution words after the target problems.

A second version was also created for this task that added a "use your gut" instruction prior to the presentation of the practice problems. To create this new version, the following was added to the completed example problem: *The best way to do this task is to go with your gut feeling.* Participants were also prompted to enter responses based on their gut feelings before beginning the practice problems.

Design and Procedure

Participants were run in sessions of up to 16 individuals. There were four conditions that orthogonally varied whether or not the RAT was preceded by the Artificial Grammar Task and whether or not the initial task included a use-your-gut instruction. The use-your-gut instruction was always manipulated in relation to the initial task. In the first condition, participants completed the RAT first (without the "use your gut" instruction), followed by the artificial grammar task. In the second condition, participants completed the artificial grammar task first without the "use your gut" instruction, prior to the RAT. In the third condition, participants completed the RAT first with the "use your gut" instruction. In the fourth condition, participants completed the "use your gut" artificial grammar task first, prior to the RAT. Each session took approximately 30 minutes.

Predictions

If performing an implicit learning task primes a less-analytic approach to problem solving, then both conditions with the artificial grammar task first should result in better RAT performance. If it is the "use your gut" instruction that is affecting solution approach, then both conditions with a "use your gut" instruction on the initial task should result in better RAT performance.

Results

The main dependent variable of interest is performance on the RAT, but for completeness performance on the artificial grammar test was analyzed. No differences were found between monolingual or bilingual samples, nor across conditions, *Fs* <1.

Monolingual Solvers

Performance on the RAT for the monolingual solvers is presented in the top panel of Figure 1. A 2x2 (initial task instruction condition x task order) analysis of variance (ANOVA) identified a significant main effect for the "use your gut" instruction on the initial task, $F(1,149) = 8.89$, $MSE = 8.82$, $p = .003$, $\eta^2 = .06$. Participants who received the instruction on the initial task (regardless of whether the initial task was the artificial grammar task or the RAT) performed better on the RAT. There was no main effect for task order, nor was there an interaction (*F*s < 1). There was no benefit from completing the artificial grammar task without the "use your gut" instruction before the RAT.

Planned comparisons using LSD showed that among participants who received the artificial grammar task first, those who received the "use your gut" instructions solved significantly more RAT problems than those who did not receive the instruction, $p = .02$. Additionally, among participants who received the RAT first, those who received the "use your gut" instruction also solved more RAT problems than those who did not receive the instruction, $p = .05$.

Bilingual Solvers

Performance on the RAT for bilingual solvers is presented in the bottom panel of Figure 1. A 2x2 (initial task instruction condition x task order) ANOVA on just the bilingual sample indicated that bilingual solvers tended to do better when they were not encouraged to use their gut, $F(1,137) = 3.41$, MSE=9.88, p=.067, $\eta^2 = .02$. Again, the main effect for task order was not significant nor was the interaction, *F*s<1.

Language Group Comparisons

A 2x2x2 (language group x initial task instruction condition x task order) ANOVA demonstrated that bilinguals performed significantly less well than monolinguals $F(1,286) = 14.28$, MSE=9.32, $p < .001$, $\eta^2 = .05$. This analysis also revealed a significant language group x initial task instruction condition interaction, $F(1,287) = 11.35$, MSE=9.32, $p < .001$, $\eta^2 = .04$. Follow-up tests using LSD showed that the "use your gut" instruction led to significantly greater performance among monolingual solvers, $p < .001$, while the two language groups did not differ in the no-gut conditions, $p = .75$.

An additional analysis on the bilingual sample examined age of fluency in English to provide converging evidence that the poorer overall performance among bilinguals was due to their linguistic status, rather than other possible differences between the samples.

(This analysis is limited to the 126 bilingual participants who provided their age of fluency in English.) Performance on the RAT correlated significantly with age of fluency, $r = -.31$, $p < .001$. Participants who achieved fluency in English at early ages performed at a similar level as monolingual solvers, whereas for other participants, performance decreased with more recent acquisition.

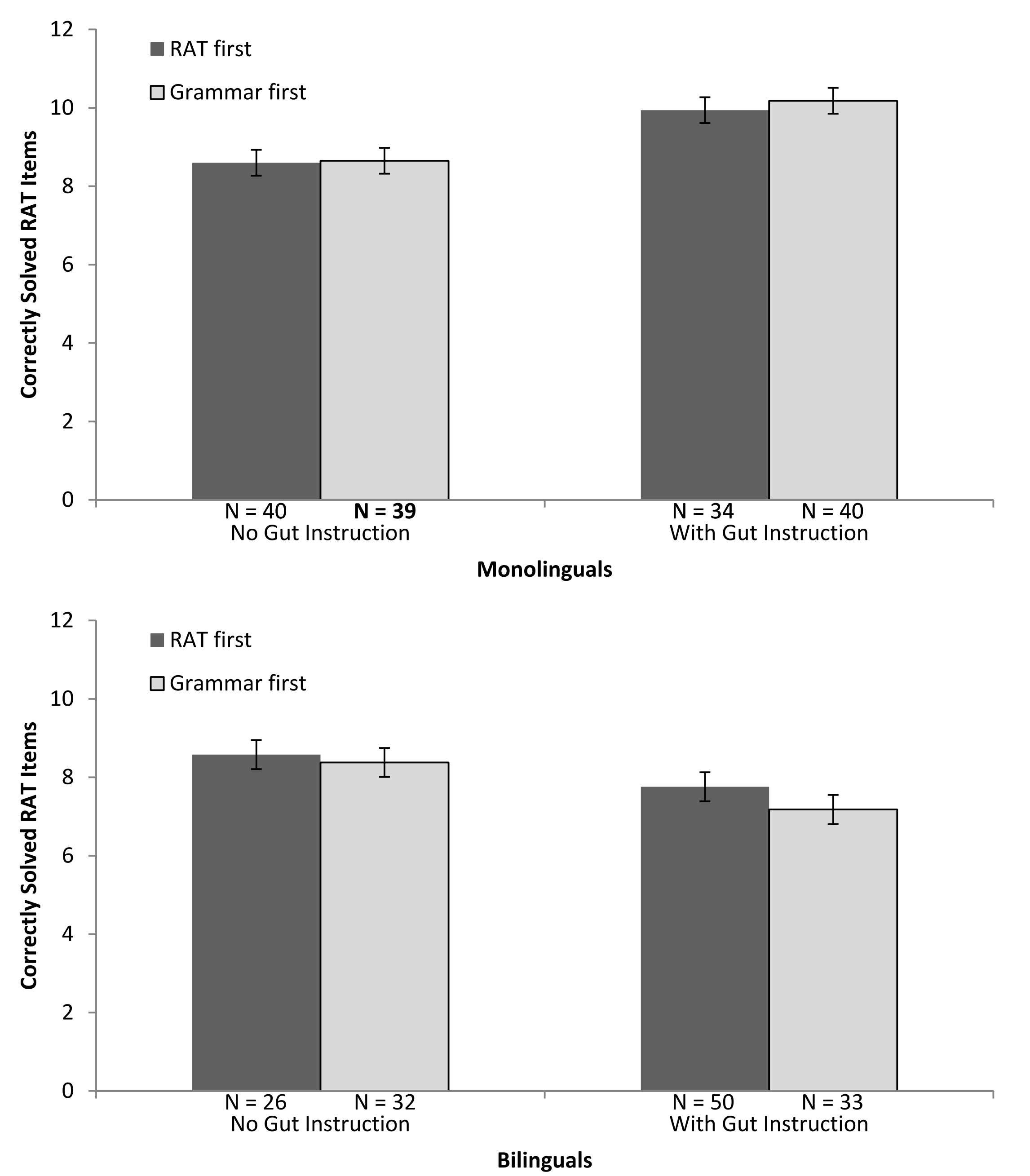


Figure 1
RAT problem solving performance by language group, task order and initial task instructional condition

Discussion

The results of the current study demonstrate that completion of an Artificial Grammar Task including the standard "use your gut" instruction before the RAT does enhance performance on the RAT for monolingual solvers. Interestingly, this effect does not seem to be due to the implicit processing style prompted by the Artificial Grammar Task itself, but rather to the "use your gut" instruction. Removing the "use your gut" instruction from the Artificial Grammar Task negated its impact on the RAT. Additionally, including a "use your gut" instruction as part of the RAT was sufficient to improve performance on this creative problem solving task. These results suggest that the inclusion of the "use your gut" instruction is encouraging participants to use a less analytic approach when solving the RAT.

Although benefits are seen whether solvers are exposed to this "use your gut" instruction as part of the RAT or as part of the Artificial Grammar Task, the reasons for improvement may be slightly different in the two conditions. When given in the context of the RAT, this instruction may be directly shifting participants away from using an effortful, targeted search strategy toward a more passive, opportunistic approach. When given in the context of the Artificial Grammar Task, the influence of this instruction is necessarily less direct. Being instructed to use their gut during the Artificial Grammar Task seems to establish a default processing approach that may be carried over to the next task.

The bilingual results are less clear, but the fact that a use-your-gut instruction made bilinguals worse than monolinguals could mean that a more analytic approach may be more helpful for this population. One possibility is that the bilingual speakers were less confident in their English skills and were less willing to "use their gut" for this task. An alternative possibility is that using your gut is a less useful instruction for bilingual solvers. It has been suggested that bilinguals must engage executive control to manage activation across their multiple lexicons (Bialystok, 2001; Costa, Hernandez, Costa-Faidella, & Sebastian-Galles, 2009). As such, bilinguals attempting a passive, opportunistic approach may have been more likely to activate non-English associates that could not possibly serve as solution words. The increased likelihood of activating these inappropriate and irrelevant associations may explain the lack of an advantage when bilinguals attempted to "use their gut" on the RAT. This explanation further suggests that those bilinguals who may have less experience in English, less knowledge of English phrases, or who may have a greater likelihood of passively activating non-English words than English phrases, should be at a particular disadvantage. Consistent with this prediction, a negative relationship was identified between the age of English acquisition and performance on the RAT.

Although Mednick first created the RAT to require broad activation and retrieval of distant associations, the present study adds to a number of other studies that have shown that RAT items may actually be solved either via more or less analytic approaches (see for example Cranford & Moss, 2012). It may certainly be the case that RAT problem solving can be aided by attentional control under some circumstances. Several studies have shown that RAT problem solving ability is generally correlated with WMC (Kane, 2004; Ricks, Turley-Ames & Wiley, 2007), although this could be for many reasons including individual differences in verbal aptitude that also are generally correlated with WMC. Yet, effective inhibitory function may be especially important when a solver needs to deal with fixation induced by the presence of incorrect associates within the context of problem solving (Smith & Blankenship, 1991; Storm & Angello, 2011). In these cases attentional control may be critical for reaching solution.

Two novel contributions from the current study are the demonstration that a solver's approach to problem solving can be manipulated by a relatively simple instruction that may facilitate a less focused or more passive search of memory. This novel result can be seen as consistent with demonstrations that reduced attentional control can be conducive to creative problem solving. A second contribution is the observation that performance on RAT items may fundamentally differ across monolingual and bilingual participants. As a result, where monolinguals' access to remote associations may benefit from less analytic approaches to solution, bilinguals may need to invoke their executive functions in order to effectively perform this problem solving task.

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