MANAGING PARADOXES FOR CREATIVITY: A PSYCHOLOGICALLY REALISTIC SIMULATION OF EMBRACING ORGANIZATIONAL TENSIONS

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Managing Paradoxes For Creativity

ABSTRACT

As globalization, competition, and environmental complexity increase, so does the intensity of paradoxical tensions faced by organizational members. Paradoxical tensions are contradictory demands of a task or situation. How organizational members react to these tensions can determine subsequent organizational performance. This study used a psychologically realistic computer simulation to examine the effect of embracing paradoxical tensions on individual creativity. We contribute to existing paradox and creativity literature by describing in detail relationship between paradoxical tensions and creativity. We also contribute to these literatures by revealing the underlying cognitive mechanism responsible for this relationship. Our processes based examination suggests ways in which challenges of organizational life may be harnessed to increase creativity and ways in which theories of creativity and paradox can be expanded.

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1. INTRODUCTION

Organizational success is often associated with creativity – the generation of novel and useful ideas (Zhou, 2008). That is, ideas that "lie outside the purview of dominant ways of thinking" lead to superior performance because they are less contested than easily discovered ideas (Gavetti, 2012: 2). As a result, a considerable body of research has focused on identifying factors that enhance creativity (Hennessey and Amabile, 2010). A well-developed body of this research focuses on individual creativity. This work explores environmental and cognitive factors that trigger the accessing and processing of novel information (Amabile *et al.*, 1996; Finke, Smith, and Ward, 1996; Perry-Smith, 2006; Perry-Smith and Shalley, 2003, 2014; Shalley, Zhou, and Oldham, 2004). One emerging subset of individual-level creativity research has focused on the effect of *embracing paradoxical tensions* on creativity (DeFillippi, Grabher, and Jones, 2007; Martin, 2009; Miron-Spektor, Gino, and Argote, 2011). Paradoxical tensions are core, yet contradictory, activities and elements of organizations (Smith and Lewis, 2011). For instance, a paradoxical tensions may stem from differing, and often competing, demands of various stakeholders (Smith and Lewis, 2011). To illustrate, corporate social responsibility highlights a double bottom line, in which performance depends on achieving both social and economic goals (Margolis and Walsh, 2003).

In a laboratory study of the effects of embracing paradoxical tensions on individual creativity, Miron-Spektor, Gino, and Argote (2011) demonstrate that participants primed with paradoxical tensions were more creative. Yet, not all paradoxical tensions are experienced equally. Some tensions may be trivial, while others may represent an existential threat. The degree of intensity with which a paradoxical tension is experienced may depend on environmental conditions. For instance, paradoxical tensions become increasingly intense in settings of globalization (Bradach, 1997), technological innovation (Iansiti, 1995), and hypercompetition (D'Aveni and MacMillan, 1990). Intensely experienced tensions may affect cognitive processing differently than trivial tensions (March and Simon, 1958; Simon, 1965). This raises the question: is the relationship between paradoxical tensions and creativity monotonic? And, how do paradoxical tensions affect the underlying mechanisms of creative cognition? The Miron-Spektor, Gino, Argote (2011) model does not provide elaboration of this aspect.

The current article seeks to utilize a psychologically realistic computer simulation to examine the effect of paradoxical tensions on creativity. Creativity research can benefit a great deal from a detailed understanding of creative cognition, including the detailed processes and mechanisms responsible for idea generation (Sun and Hélie, 2015). Some of these processes have been tackled with the use of computational modeling and simulations of psychologically realistic cognitive architectures (Dollinger, 2011; Sun, 2001, 2014). A cognitive architecture specifies the essential mechanisms, structures, and processes in the form of a domain-generic computational model, which can be used for a broad analysis of cognition and behavior (Sun, 2006). The function of such a simulation is to provide an infrastructure that enables a deeper understanding of various components and processes of the mind. In this way, a simulation serves as the initial set of assumptions to be used for further theory development. Computer models of creative problem solving have already been used to account for phenomena similarly complex to those we study here, such as research output in the scientific community and organizational decision-making (Sun and Naveh, 2004).

To generate a more fine-grained understanding of the relationship between paradoxical tensions and creativity, we employ a cognitive architecture that describes creativity based on explicit-implicit interaction (EII) theory (Hélie and Sun, 2010a). EII theory integrates many existing theories of creative problem solving, such as theories of incubation, insight, and creativity. Although EII theory is a high-level decomposition of creative cognition, it nonetheless suggests process-based explanations that are sufficiently detailed for implementation using a computer model. In the current article, we present the results of a simulation of EII theory that models the relationship between paradoxical tensions and creative outcomes. We start by simulating three studies described in Miron-Spektor, Gino, Argote (2011). Once we have validated that a computer model of EII theory can account for the data in those studies, we simulate a range of intensities of paradoxical tensions and observe their effects on creativity.

Our findings reveal that the relationship between paradoxical tensions and creativity is non-monotonic. That is, creativity increases for moderately intense tensions, but decreases for highly intense tensions. We also observe the underlying mechanisms responsible for this relationship. Paradoxical tensions increase creativity when they encourage *tolerance for novelty*. More specifically, tolerance for new and uncommon ideas induced by embracing organizational contradictions could be the primary driver of enhanced creativity. Highly intense tensions reduce creative output when they lead to *integration between highly disparate concepts*. In such a case, creativity is reduced because of uncertainty about which idea represents the best solution to an existing problem. That is, embracing paradoxical tensions may lead to uncertainty that one idea is superior to all others.

Our study offers three distinct contributions. First, we offer a rare examination of the mental processes responsible for mediating the effect of paradox on creativity. Second, we advance understanding of when organizational contradictions may increase creative performance and when they may not. Finally, we add to earlier work (Denison, Hooijberg, and Quinn, 1995;

Lewis, Andriopoulos, and Smith, 2014; Miron-Spektor *et al.*, 2011; Quinn, 1988; Smith, 2014; Smith and Tushman, 2005) on paradox theory by suggesting how paradoxical tensions may be harnessed to enhance creativity.

2. CURRENT PERSPECTIVES ON PARADOXICAL TENSIONS AND CREATIVITY

Paradoxical Tensions as Triggers of Integrative Complexity

As people attempt to make sense of a complex, ambiguous, and intricate world, they simplify reality with polarized distinctions (Kelly, 2003). Such artificial polarizations help individuals distinguish related, but contradictory, concepts through categorization (Roach and Lloyd, 1978). While these polarizations allow people to make sense of reality, they can oversimplify a complex world.

Smith and Lewis (2011) suggest that artificial polarizations persist in organizations as latent tensions. Latent tensions are contradictions unnoticed by organizational members. Such tensions are dormant, unperceived, or ignored, until they are accentuated by environmental or cognitive factors. Scarcity of resources, plurality of views, or organizational change can render latent tensions salient. Once salient, tensions become recognized as paradoxes of organizational life. Environmental conditions will dictate the degree of paradoxical intensity for an individual. For instance, globalization may intensify the tensions between diverging viewpoints (Bradach, 1997); technological innovation may intensify the tension between building up or destroying the past to create the future (Andriopoulos and Lewis, 2009, 2010); and hypercompetitive environments may intensify the contradictory demands on scarce resources (Smith and Tushman, 2005).

Embracing paradoxical tensions reveals the otherwise hidden complexity of a task or situation. When paradoxical tensions are embraced the otherwise separated contradictions (e.g., good vs. bad) are recombined (Smith and Lewis, 2011; Smith and Tushman, 2005). Thus, the complexity of the world is reveled, and can, at least momentarily enhance creativity. For instance, embracing the divergent viewpoints inherent in situations of cultural diversity allows an individual to see an issue from a different vantage point than she did before (Leung *et al.*, 2008). The cognitive mechanism believed to be responsible for the relationship between paradoxical tensions and creativity is integrative complexity (Miron-Spektor *et al.*, 2011; Smith and Lewis, 2011).

Integrative Complexity

Embracing paradoxical tensions tends to trigger a more integratively complex thinking style. The concept of integrative complexity was developed to capture differences in thinking style – that is, how individuals react to environmental stimuli (Schroder, Driver, and Streufert, 1967; Suedfeld and Tetlock, 2001; Tetlock, Peterson, and Berry, 1993; Tetlock and Suedfeld, 1988; Wong, Ormiston, and Tetlock, 2011). Integratively complex thinkers are more likely to generate linkages among disparate concepts and more willing and capable of tolerating different perspectives. They are more flexible, open-minded, and take a multidimensional stance towards the world. High levels of integrative complexity reflect an actor's ability to generate and consider more ideas related to one concept or category and, therefore, enhance creativity. In contrast, integratively simple thinkers dislike ambiguity and form dichotomous impressions (e.g., good vs. bad) about people, events, and issues. Integratively simple thinkers seek rapid cognitive closure and are often characterized by cognitive rigidity and inertia. Simple thinkers are more likely to utilize "either/or" rather than "both/and" thinking when facing contradictions.

Two cognitive indicators can be used to categorize a thinking style as integratively complex or integratively simple: *evaluative differentiation* and *conceptual integration* (Schroder *et al.*, 1967; Tetlock *et al.*, 1993).

Evaluative Differentiation. Evaluative differentiation (henceforth called differentiation) entails "the capacity and willingness to tolerate different points of view" (Tetlock *et al.*, 1993: 500). Individuals that score high on differentiation actively seek out information about the world and are open to new experiences. They are also likely to be good listeners, even considering points of view they themselves may not believe in or are unsure about. In contrast, individuals that score low on differentiation hold contempt for others' points of view and dislike novel stimuli, and are more likely to dismiss novel stimuli than are those high on differentiation.

Conceptual Integration. Conceptual integration (henceforth called integration) is "the capacity and willingness to generate linkages between [ideas]" and "to appreciate interactive patterns of causation" (Tetlock *et al.*, 1993: 500). People that score high on integration can see more interactions and connections among points of view. As a result of processing multiple and multidimensional linkages among concepts, individuals high on integration appear less predictable and stable in their behavior. Individuals scoring low on integration fail to appreciate nuances and subtleties, because they fail to see interdependencies among concepts.

While embracing paradoxical frames tends to increase integrative complexity and therefore enhance creativity, the operation of cognitive mechanisms responsible for this relationship is unclear. We explore this relationship using a simulation model based on EII theory.

3. EXPLICIT-IMPLICIT INTERACTION THEORY AND SIMULATION MODEL

EII theory relies on five basic assumptions. The first assumption is the existence of explicit and implicit knowledge and processing (Sun, 2002). Explicit processes are typically consciously available and perform some form of rule-based reasoning using relatively crisp and exact conditions. In contrast, implicit processing is typically not consciously available, and satisfies soft conditions using ‘associative’ processing. Second, explicit knowledge and implicit knowledge are often “redundant”: although they are represented differently, they may contain the same knowledge (e.g., consider the similarity and differences between the explicit knowledge of how to perform a tennis swing versus the implicit skill of performing the swing). Third, explicit and implicit processes are invoked simultaneously in most tasks under most circumstances. As such, both processes can end up with compatible or conflicting conclusions that contribute to the overall output. Fourth, the results of explicit and implicit processing are integrated when generating ideas. As a result, no task is purely explicit or implicit. Instead, the ‘explicitness’ or ‘implicitness’ of a task lies on a continuum. Fifth, processing is often iterative and potentially bidirectional between implicit and explicit processing. If the integrated outcome of explicit and implicit processing does not yield a definitive result (i.e., a result in which one is highly confident) and if the time constraint has not been met, another round of processing may occur.

The preceding assumptions allow for a conceptual model that captures creativity according the Wallas’s (1926) analysis of creative problem solving (see Figure 1). Wallas’s first stage of creative problem solving is the preparation stage. Wallas described the preparation stage as involving logic and reason. This is captured by explicit processing in EII theory: Explicit knowledge is usually rule-based, which includes logic-based reasoning as a special case. Also, the preparation stage has to be explicit in EII because people are responding to (explicit) verbal instructions, forming representations of the problem, and setting goals.

---------------- Insert Figure 1 about here ----------------

The next stage, incubation, happens when an impasse is reached and the problem solver stops attempting to solve the problem. Incubation can last from a few minutes to many years, during which the attention of the problem solver is not devoted to the problem. Incubation is mostly implicit processing in EII. This is consistent with EII's account of the difference of conscious accessibility between explicit and implicit knowledge.

The third stage, insight, is the "spontaneous" manifestation of the problem and its solution in conscious thought (i.e., the "Eureka!" moment). In EII, insight is obtained by the process of explicitation, which makes the output available for verbal report. It is worth noting that the intensity of insight is continuous (Bowers et al., 1990). Correspondingly, explicitation is continuous in the EII theory (using an 'internal confidence level' or ICL; Helie & Sun, 2010a). In particular, when the ICL of an output barely crosses the explicitation threshold, the output is produced but does not lead to an intense "Aha!" experience. In contrast, when the ICL of an output suddenly becomes very high and crosses the explicitation threshold, a very intense experience can result. According to the EII theory, intense insight experiences most likely follow the integration of implicit and explicit knowledge, as it can lead to a sudden large increase of the ICL and synergy. The fourth stage, verification, is used to ascertain the correctness of the insight solution. Verification is similar to preparation, because it also involves the use of deliberative thinking processes (with logic and reasoning). If the verification stage invalidates the solution, the problem solver usually goes back to the first or second stage and this process is repeated. Similar to the preparation stage, verification is accounted for by explicit processing in EII.

Previous Work

EII theory integrates existing theories of creative problem solving by detailing the processes involved in key stages of the ideation process. It does so with enough precision to allow implementation using a computer model. A computer implementation of EII theory has been used to account for creativity in several instances (Hélie and Sun, 2010a). These include incubation in a lexical decision task, a rare-word association decision task used to test the effect of incubation on the recovery of infrequently used words (Yaniv and Meyer, 1987); incubation in a free-recall task, a retrieval task used to measure the effect of a respite period on the number of new words recalled (Smith and Vela, 1991); and insight in problem solving tasks, an insight problem that requires participants to explain why the sight of a shotgun replaces a man's need for a glass of water (i.e., because he had the hiccups) (Durso, Rea, and Dayton, 1994). In the first two examples, EII theory accounts for unconscious work that leads to retrieval of distant memories. In the last example, EII accounts for an individual's ability to explore unlikely explanations for a novel situation.

Computational Model

Below we present key equations of the computational model essential for understanding the content of this article. The interested reader is referred to the Appendix for a more detailed mathematical exposition of EII.

The first key equation of EII theory formalizes the decision function:

$$P(y_{[\text{integrated}]i}) = \frac{e^{y_{[\text{integrated}]i}/\alpha}}{\sum_j e^{y_{[\text{integrated}]j}/\alpha}} \qquad (1)$$

where $y_{[integrated]i}$ represents a decision maker's support for hypothesis i and α is the disturbance parameter. The decision function determines an individual's confidence in an idea and the probability that one idea is selected over another (Helie & Sun, 2010a). The disturbance parameter (α) in the decision function is used to represent the breadth of search over the entire solution space. That is, low disturbance favors a narrow search and stereotypical responses; in contrast, high disturbance leads to a more complete and integrated search. As such, a higher disturbance parameter will favor selection of novel ideas. If integration is the ability to see nuances and subtleties (Tetlock *et al.*, 1993) and if it is associated with a widening of one's search for information (Satish, 1997), than it follows that it can be represented in EII theory by a higher disturbance value. In the computer model, we simulate integration by varying the disturbance parameter. Past simulations with EII have used a higher disturbance value to account for a more diffuse search in memory (Hélie and Sun, 2010a). One major goal of the replication of the studies in Miron-Spektor, Gino, and Argotte (2011) is to test the adequacy of EII to model integration.

Another important aspect of EII is that an individual has a subjective confidence evaluation of the appropriateness of the selected idea (denoted by internal confidence level or ICL). If the individual's ICL crosses a subjective threshold (ψ in the model), insight or the generation of an idea occurs. In other words, insight does not occur if agents are not sufficiently confident in an idea (based on ψ). Differentiation is the capacity and willingness to tolerate different points of view. Moreover, individuals that score high on differentiation are more likely to tolerate points of view they themselves may not believe in or are unsure about. We relate an individual's subjective threshold (ψ) to the concept of differentiation because both differentiation and the subjective threshold relate to consideration and tolerance of a broad range of ideas. Note that a *lower* ψ is used to represent *higher tolerance* for novel ideas or greater differentiation.

If the ICL in EII crosses a subjective threshold, processing is stopped and an idea is output. The ICL, therefore, serves as a sort of metacognitive monitoring system used to determine whether processing should continue (Helie & Sun, 2010a). The ICL is estimated using the statistical mode of Eq. 1 (i.e., $Max[\text{P}(y_{[integrated]i})]$). If the ICL for one or more ideas exceeds the threshold, reasoning stops and an idea is output. If the ICL fails to reach or exceed the threshold, another round of reasoning is initiated.

The following simplified example illustrates how the decision function in Eq. 1 operates. In this example we will work with only two possible outcomes: idea A and idea B. After the decision maker engages in implicit and explicit processing, her support for idea A ($y_{[integrated]A}$) is 0.60 and her support for idea B ($y_{[integrated]B}$) is 0.40. Support represents the activation strength of a node after the result of explicit and implicit processing has been integrated. In this example, explicit and implicit processing has resulted in a stronger activation of idea A. The ultimate selection of A over B depends not only on the result of processing, but also on the decision makers willingness to tolerate novel ideas and capacity to search for new ideas. Low disturbance levels (i.e., low α) in the decision function exaggerate the probability differences between ideas, while high disturbance levels (i.e., high α) tend to reduce the probability differences. With a disturbance value of 1, the probability that A is selected is 0.55 $\left(P(A) = \left(\frac{e^{0.6/1}}{e^{0.6/1}+e^{0.4/1}}\right) \cong 0.55\right)$ and the probability that B is selected is 0.45. The ICL (i.e., $Max[y_{[integrated]i}]$) in this example is 0.55 (i.e., $Max[\mathrm{P}(y_{[integrated]A}), \mathrm{P}(y_{[integrated]B})] = \mathrm{P}(y_{[integrated]A})$). In contrast, lower disturbance values will exaggerate the differences between ideas $\left(e.g., \alpha = 0.1;\ P(A) = \left(\frac{e^{0.6/0.1}}{e^{0.6/0.1}+e^{0.4/0.1}}\right) \cong 0.88;\ ICL \cong 0.88\right)$, while higher disturbance values will decrease them $\left(e.g.,\ \alpha = 10;\ P(A) = \left(\frac{e^{0.6/10}}{e^{0.6/10}+e^{0.4/10}}\right) \cong 0.51;\ ICL \cong 0.51\right)$. Hence, if the threshold (ψ) is 0.6, an idea would be output in the low disturbance example (0.88 ≥ 0.60), but not in the high disturbance example ($0.51 < 0.60$). If the threshold is 0.4, confidence would exceed the threshold in the two higher disturbance scenarios (α = 1 and α = 10), and an idea would be output. From the final distribution of activations an idea is stochastically chosen for output.

While the EII model has been validated over a range of situations (Durso *et al.*, 1994; Schooler, Ohlsson, and Brooks, 1993; Smith and Vela, 1991), we begin by examining its validity for describing the effects of paradoxical frames on creative performance. To do so, we replicate the remote association task (RAT) experiments performed in Miron-Spektor, Gino, and Argote (2011).

Experimental Setting

Each of Miron-Spektor, Gino, and Argote's (2011) studies consist of two parts. The first part is a priming task used to manipulate the cognitive frames of participants. The second part is a creativity task used to assess participant creativity. The creativity test is a set of remote association task (RAT) problems (Mednick, 1962), and the studies' dependent measure is the number of problems solved. In each study, the prediction is that participants primed with a paradoxical tension will solve a greater number of RAT problems.

Study 1. During the first part of study 1, cognitive frames were manipulated using a priming task in which participants read a description of a product. Although the product was the same in all primes, several elements of the description were varied to create the treatment condition, which was used to prime the paradoxical tension. During the second part of study 1, participants completed RAT problems, a widely used test of creativity (Mednick, 1962). During this test, participants were asked to find a word that is semantically associated with all three cue words provided to them. Participants were given ten RAT problems and had six minutes to complete the test.

Study 2. In study 2, Miron-Spektor, Gino, and Argote (2011) test whether paradoxical tensions lead to increased creativity when individuals themselves activated these tensions. Namely, in part one of study 2, participants were given a "Recall Skill" task, in which they were asked to engage in writing either interesting statements they encountered in the past (i.e., control) or paradoxical statements that they think are interesting (i.e., treatment). In study 2, participants had four minutes to solve as many of seventeen RAT problems as they could.

Study 3. Study 3 uses a different prime (Picture Story Exercise (Tetlock *et al.*, 1993)) than study 1 and 2, but otherwise replicates the procedures in the previous 2 studies for priming subjects with a paradoxical tension condition and a control condition. Like in the previous studies, creativity is measured by performance on the RAT task. We forgo presenting study 3's results because it resembles the procedure in study 2. That is, time limit to solve the task, number of RAT problems, and number and type of primes (i.e., 1x paradoxical frame and 1x control frame) remain the same from study 2.

Study 4. In study 4, an adaptation of the priming task in study 1 was used. Like in study 1, the same procedure was used across conditions, but the manipulation was varied across conditions in order to prime a *low differentiation-low integration* condition (D_LI_L), a *high differentiation-low integration* condition (D_HI_L), a *low differentiation-high integration* condition (D_LI_H), and a *high differentiation-high integration* condition (D_HI_H). Like in previous RAT experiments, creativity was measured with the number of correct solutions. In study 4, creativity was assessed using ten RAT problems, which participants had four minutes to solve.

Simulation Setup

A schematic of the implementation of EII theory as used in the simulations is shown in Figure 2. In Figure 2, the top level is a linear connectionist network used to implement explicit rule-based processing while the bottom level is a Hopfield-type nonlinear connectionist network used to implement implicit associative processing. The integration function is represented using the rightmost square of Figure 2. The integration and decision function (Eq. 1) is used to transform the results of explicit and implicit processing into a final activation pattern of words.

--------------- Insert Figure 2 about here ----------------

Structure of top level. In the top (explicit processing) level of the model the left layer was used to represent cue words, while the right layer was used to represent the target word (the creative solution to a RAT problem) and distractor words (noncreative solutions). One example of a RAT problem may be presenting the participant with the cue words "rat, blue, cottage." The participant is required to find a fourth target word associated with all three of the cue words. Distractor words are closely associated with one of the cue words and are therefore words that are most likely to come to mind when the cue word is activated. Cue-distractor pair examples are "rat-rodent", "blue-sky", and "cottage-vacation". However, no distractor is associated with *all* three cue words. The target word in this case is "cheese".

In the simulation model each node in the top level represented a cue, target, and distractor. Each cue was associated by a link to a target and two distractors. That means that for each remote association problem (reading of the 3 cue-words) a simulated agent recalled seven potential solutions (6 distractors and 1 target), only one of which was correct. To represent the associative hierarchy of words (i.e., that stronger associations between a cue and distractors than a cue and a target) (Mednick, 1962: 222–224), each distractor was assigned a weight twice that of the target.

Structure of bottom level. In the bottom (implicit processing) level of the simulation model, a bipolar vector was randomly generated to represent implicit knowledge. A Hebbian learning rule was then used to pretrain top level associations in the bottom level. The Hebbian learning rule allows for the learning of associations between the randomly generate bipolar vectors in a weight matrix, **W**. These associations represent those of the associations between nodes in the top level. During recall, the weight matrix was used in the implicit system to make associations between cues and targets[1]. An important difference exists between the structure of the top and bottom levels. The top-level knowledge structure represents crisp, hard constraints and therefore only allows for rules-based processing. In contrast, the bottom-level knowledge structure is associative and represents soft constraints (Hélie and Sun, 2010b). For example, the proof of a mathematical theorem uses the strict rules (which must be completely satisfied) of explicit processing, while arguing that robins and blue jays are similar can be done using soft constraints.

Information Processing. Simulated agents solved the RAT problems sequentially, one at a time.[2] The number of RAT problems and processing time varied depending on the studies in Miron-Spektor, Gino, and Argote (2011). For studies 1 and 4, agents were given 10 problems and had a max of 1,028 iterations in the bottom level (350ms/iteration for a six minute recall time) to solve as many problems as they could (Helie & Sun, 2010). For study 2, agents were given 17 problems and had a max of 686 iterations (350ms/iteration for a four minute recall time) to solve as many problems as they could. An iteration is a round of updating of all the nodes in the bottom level of the computer model. According to Sun and Zhang (2004), each iteration in the bottom level of the model takes about 350ms of psychological time.

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[1] Interested readers can refer to Chartier and Proulx (2005) for more detail about the Hebbian learning rule that is used in EII.

[2] For each problem, the values given to the task related parameters were: $n = 3, m = 7, r = 100,\ s = 25,\ p = 10,\ Epochs = 15$ *Note.* n is the number of nodes in the left layer of the top level, m is the number of nodes in the right layer of the top level, r is the number of nodes in the bottom-level network, s is the number of nodes in the bottom-level network that are connected to the left layer in the top level, p is the number of spins used to pretrain the bottom-level network, Epochs is the number of learning trials used to pre-train the bottom-level network. For details, see Helie & Sun (2010).

To simulate working through a RAT problem, a stimulus (reading of the first cue word) activated a node in the left layer of the top level (i.e., explicit knowledge) and, using the top-down transmission function (i.e., implicitation), the corresponding representations in the bottom level (i.e., implicit knowledge). Explicit rules were applied in the top level and the information was processed in the bottom level. Following this processing, the output of both the bottom and top level were integrated to form a "hunch" or "running hypothesis" about the correct response. The hunch was stored in buffer memory. Next, a stimulus activated the next node (i.e., the next cue word) in the left layer of the top level and the corresponding nodes in the bottom level. After processing, the results were integrated and added to the results of the previous process, forming an updated running hypothesis. The same process was repeated for the last cue word. Once all three cue words were read and processed, a solution to the RAT problem was selected using the decision function show in Eq. 1, the ICL was calculated as described above, and it was compared to the subjective threshold to determine whether a solution was generated.

In the simulation, an agent verified the accuracy of its response using abductive reasoning (Johnson and Krems, 2001; Pearl, 2000). Alternating between abductive and deductive reasoning is argued to be a common cognitive strategy (Rips, 1994). The verification phase of the creative cognition processes "closely resembles the first stage of processing" (Wallas, 1926: 85–86), and should, according to EII theory, involve mainly explicit processing (Hélie and Sun, 2010b: 1001). Therefore, verification of a response as correct was done by propagating the response backwards in the top level, from right to left (i.e., if the chosen word in the right layer is correct, it should activate all three cue words in left layer). For a correct answer, the agent proceeded to the next RAT problem. If the response was incorrect, the agent attempted the same problem again until a solution was found or time expired. If the agent could not find a correct solution to a problem within the allowed time, a best guess was made (i.e., a word was stochastically chosen form the current activations). This simulates the relative accuracy with which agents can judge their answers as correct or incorrect, but the difficulty of finding the creative answer. Judgments about the accuracy of a selected word combined with repeated attempts to find the correct word represent agents "getting stuck" on incorrect solutions.

Rationale and Explanations of Simulation

Conceptual explanation. According to EII theory, a RAT problem produces a simultaneous search of both explicit and implicit knowledge. In this simulation, every agent was given the same explicit knowledge structure. That is, all agents read the same list of cue words and all had the same vocabulary.

Primes differ from controls on two dimensions. This difference is only apparent during the decision stage of cognitive processing. First, primed agents are more likely to search broadly in memory for a solution. This means considering even those associations that are unusual. Second, primed agents are more tolerant and accepting of novel ideas.

Once an idea is generated, all agents use the same metacognitive criterion: *if* they feel confident in a solution *then* this solution is tested using abductive reasoning. If abductive reasoning confirms the solution, the solution is output, otherwise the agent makes another attempt, or if out of time, makes a best guess based on the current running hypothesis. This process is iterated for all RAT problems or until the agent runs out of time.

Mechanistic explanation. When agents start a RAT problem, a stimulus activates a node representing that cue word in the left layer of the top level and, through implicitation, vectors representing the cue word in the bottom level are activated. Once all three cue words associated with a RAT problem are processed, the disturbance is added in constructing the decision function and a hypothetical idea is generated. Low disturbance should result in generating an idea in accordance with the current knowledge structure, which tends to be one favoring close associations, which, in this context, is uncreative. When disturbance is increased, ideas that are somewhat distant from the stimulus are likely to be sampled, increasing the probability of a creative solution. As disturbance is increased, however, ICL declines. Because high disturbance levels reduce the probability differences among hypothesis, they also reduce certainty that one hypothesis must be appropriate and others not appropriate. A reduction in ICL without a corresponding change in the subjective threshold may lead to lack of insight because insight occurs when the ICL crosses the threshold.

This explanation aligns with the effects of embracing paradoxical tensions on creativity obtained by Miron-Spektor, Gino, Argote (2011) and argued by other paradox theory scholars (Lewis, 2000; Smith and Lewis, 2011; Smith and Tushman, 2005).

4. SIMULATION RESULTS

Simulation results: Study 1. To simulate the results of Miron-Spektor, Gino, Argote's (2011) study 1, one thousand simulations were run for both the control and treatment conditions. We treated the three control conditions (creativity-frame, efficiency-frame, and creativity-efficiency-frame) equally, using control levels of disturbance ($\alpha = 550$) and threshold ($\psi = 0.45$) to simulate low level of integration and differentiation, respectively. The number of RAT problem solved in the simulated control condition ($M = 3.87$) closely replicates the average of the three control conditions ($M = 3.88$) obtained from human participants. To simulate the treatment condition (i.e., embracing paradoxical tensions), we increased integration ($\alpha = 1{,}000$) and differentiation ($\psi = 0.25$). Higher α and lower ψ values are used to simulate agents more likely to identify linkages among concepts and more likely to tolerate novel ideas. Like in Miron-

Spektor, Gino, and Argote (2011) first study, the number of correct solutions (M = 7.03) in the treatment condition of our simulation was higher than it was in the control conditions. The results shown in Figure 3a demonstrate that a simulation of EII theory can account for the experimental data of study 1.

--------------- Insert Figure 3 about here ----------------

Simulation results: Study 2. To account for the results from study 2, we again ran one thousand simulations for both the control and treatment conditions. To replicate the control and paradoxical tension conditions, we used the same values for α and ψ as in study 1. We adjusted values for the number of RAT problems and time limit to match those of study 2. Our results account for those of Miron-Spektor, Gino, Argote (2011). The paradoxical tension group solved more problems (M = 5.01) than the control group (M = 3.06). A comparison of simulated and experimental results can be found in Figure 3b. Increasing disturbance and decreasing the subjective threshold increased the number of correct solutions. EII was able to account for the difference in creative performance between paradox and the control conditions when disturbance (α) and threshold (ψ) parameters were controlled for and time limit and number of RAT problems was changed.

Simulation results: Study 4. In study 4, Miron-Spektor, Gino, Argote (2011) manipulate integration and differentiation independently. We replicate their study by varying the disturbance (α) and the threshold (ψ) variables independently in the simulation, using the same parameters as before. We use $\alpha = 550$ and $\alpha = 1{,}000$ to model control and treatment levels of integration, respectively, and $\psi = 0.45$ and $\psi = 0.25$ to model control and treatment levels of differentiation, respectively. Like in previous simulations, we ran 1,000 trials for each condition.

In the *low*-differentiation-*low* integration condition ($D_L I_L$) simulated agents solved an average of 3.0 RAT problems, compared to 2.9 by human participants. In the *low* differentiation-*high* integration condition ($D_L I_H$) simulated agents solved 2.9 RAT problems correctly, whereas human participants solved an average of 3.0 correctly. In the *high* differentiation-*low* integration condition ($D_H I_L$) simulated agents solved an average of 3.8 RAT problems correctly, the same as human participants. In the *high* differentiation-*high* integration condition ($D_H I_H$) simulated agents solved 5.0 RAT problems correctly, compared to 5.7 by human participants. Like the experimental data, simulation results demonstrate separate effects of differentiation and integration on creativity. These results are presented in Figure 4. Overall, the results of our EII simulation accounted for the effects of differentiation and integration on creativity found by Miron-Spektor, Gino, Argote (2011).

Next, we use the simulation to study the effect of different levels of paradoxical tension intensity on creativity of agents.

--------------- Insert Figure 4 about here ----------------

5. ANALYSIS

One advantage of using a computer model to study the effects of paradoxical frames on creativity is that we can simulate intensity of paradox by varying the levels of integration and differentiation. We now address questions that extend findings of Miron-Spektor, Gino, Argote (2011). Specifically: Is the relationship between paradoxical frames and creativity monotonic? And, how do the underlying mechanisms of differentiation and integration interact to produce creative results?

Effects of Increasing Integration

Figure 5 presents the number of correct RAT solutions for a range of integration levels, under the two differentiation conditions in Miron-Spektor, Gino, Argote: low (ψ = 0.45) and high (ψ = 0.25). The four black dots in the figure mark the results from Miron-Spektor, Gino, Argote's (2011) study 4. Figure 5 presents two interesting findings: (i) the non-monotonic relationship between paradoxical frames and creative output and (ii) the difference in creativity between the low and high differentiation conditions.

----------------Insert Figure 5 about here ----------------

The difference in creativity between the low and high differentiation conditions is a result of the difference in tolerance for novelty these two conditions represent. For low levels of integration, output is relatively similar under the two conditions. Because low integration represents a narrow search of the solution space, tolerance for novelty is unlikely to be important when novel ideas are unlikely. The difference in creativity between the two conditions increases with integration. A broad search of the solution space interacts positively with tolerance for novel solutions, leading to a divergence in creativity between the two conditions for high levels of integration.

We also observe that a high degree of integration stymies creativity – under both (low and high) conditions of differentiation. In fact, this is true for all conditions of differentiation and integration[3]. This leads us to submit that the relationship between paradoxical tensions and creativity is non-monotonic. The internal confidence level accounts for this non-monotonicity. In EII theory, higher integration can reduce internal confidence because of the number of ideas generated by higher integration. Simply put, higher integration provides an agent with more options. Although a greater number of options can result in enhanced creativity, it can also

[3] Interested readers can jump ahead to Figure 7. It graphically demonstrates this observation.

reduce certainty that any one idea is appropriate over all ideas. As a result, agents with multiple options are more likely to “doubt” the validity of their creativity. Doubt can lead to another round of processing, which delays output, possibly indefinitely.

All in all, the above observations reveal that the relationship between paradoxical tensions and creativity is non-monotonic. That is, there exists an inflection point (in the simulation this point is represented by $\alpha = 1{,}000$ for $\psi = 0.45$) beyond which a higher degree of paradoxical intensity may decrease creativity. As such, we propose that:

Result 1a: The relationship between paradoxical frames and creativity is parabolic.

Result 1b: The underlying mechanism responsible for the parabolic relationship is conceptual integration, which reduces creativity by lowering internal confidence in creative ideas.

Effects of Increasing Differentiation

Figure 6 presents the number of correct RAT solutions for a range of differentiation levels. The two lines in the figure represent the two integration conditions in Miron-Spektor, Gino, Argote’s 4th study: low ($\alpha = 550$) and high ($\alpha = 1{,}000$). The four dots in the figure mark the results of that study. The new finding presented in the figure is the intersection point of the two integration conditions at $\psi = 0.46$. To either side of this intersection point one of the integration conditions produces more creative results. To the right of this point, the high integration condition produces more creative results. To the left of this point, the lower integration condition is more creative. These results demonstrate that an increase in integration, without a simultaneous increase in differentiation, may result in overall lower creativity.

These results highlight the critical role played by the differentiation mechanism between paradoxical frames and creativity. Differentiation represents perspective taking, cognitive flexibility, and open-mindedness, while integration represents broad search and recombinations of distant knowledge to form new ideas. Figure 6 highlights that creativity is highest when tolerance for novelty is enhanced. This is not the case for broad search of the solution space. In fact, when tolerance for novelty is low and the search for ideas is broad, creativity is lower than it would be were the search narrow.

Result 2: The positive relationship between paradoxical frames and creativity is more sensitive to differentiation than it is to integration.

The previous result suggests that the critical mechanism responsible for the positive relationship between paradoxical tensions and creativity is tolerance of novelty. Thus, paradoxical tensions enhance creative performance because they increase an individual's capacity and willingness to tolerate different points of view, and not necessarily because they lead to integration of different knowledge. In fact, should some stimulus increase integration without simultaneously enhancing differentiation, creative output may be decreased.

----------------Insert Figures 6 & 7 about here ----------------

Figure 7 presents the interaction between differentiation and integration. As this figures illustrates, the highest levels of creative outcomes are generated when integration is moderate and differentiation is high. The dark peak at the top of the graph depicts this relationship. It is also important to note that a high degree of integration is not at all necessary for creativity. The ridge at the right side of the graph illustrates this observation. As suggested by the previous proposition, Figure 7 highlights that creative results may be more sensitive, in general, to increases in differentiation levels than to increases in integration levels. This leads us to our final result:

Result 3: Paradoxical frames are most likely to enhance creative performance when the degree of integration is moderate and the degree of differentiation is high.

6. DISCUSSION, LIMITATIONS, AND CONCLUSION

We contribute to the existing creativity and paradox literatures with new findings on the non-monotonic effect of paradoxical tensions on creative outcomes. Some paradoxical tensions may reduce creative output (R1a). The mechanism responsible for this relationship is integration (R1b). Integration increases uncertainty in ideas, which can lead individuals to fail to select a novel idea. We also observe that creativity appears to be more sensitive to changes in differentiation than integration (R2). That is, tolerance for novelty may be the primary mechanism responsible for the positive relationship between paradoxical frames and creativity. While paradoxical frames may result in creativity because they induce individuals to recombine new ideas, paradoxical frames may lead to creativity even when this is not the case (R3). This suggests that the positive effects of paradoxical tensions on creativity may be harnessed by increasing perspective taking, and other differentiation enhancing strategies. Our processes based examination suggests ways in which the positive effects of paradoxical frames may be harnessed to enhance creativity. In agreement with paradox theory, we find that embracing paradoxical tensions leads to more creative outcomes.

The intensity of paradoxical tensions is time and space dependent. A tension perceived as intense at one point in history may not appear as intense in the present or at some point in the future. The aging and growth of an organization provides one example. For start-ups, scarcity of resources (Baker and Nelson, 2005) and legitimacy (Zott and Huy, 2007) are existential issues. As such, these issues are perceived as more important to new ventures than they are to incumbents. The search for new rents (Christensen, 1997; Henderson and Clark, 1990) and organizational change (Boeker, 1997; Greve, 1998) are issues likely to be salient in larger, more established organizations than they are to smaller, more entrepreneurial organizations.

General Discussion

Managing paradox for creativity and harnessing the underlying mechanisms responsible for this relationship involves a deep understanding of the interactions between ecosystem and individual level variables. Indeed, we propose that some of the time embracing paradoxical tensions may reduce creativity. Even still, creativity need not be desirable. The production of creative outcomes does not guarantee their economic value. Thomas Edison holds the record for the most patents awarded to a single person by the US Patent office. As pointed out by Simonton (1997), not all of these patents turned out to be profitable. As it happens, the cost of one of these useless patents exceeded Edison's profits for the electric light bulb.

Although beyond the scope of this study, this reasoning implies the need for a further discussion about the economic value of creativity, and therefore the economic performance implications of embracing paradoxical tensions as triggers of creativity. Good managerial judgment is necessary when deciding under which circumstances embracing paradoxical tensions will increase profitability and strengthen competitive advantage. Arguably, the most valuable tool in a manager's toolbox for managing paradoxical tensions may be the ability to recognize low differentiation – namely, too little tolerance of other points of view – or too much integration – namely, too much or too little creation of linkages across ideas.

A recent review article of innovation in the workplace (Anderson, Potočnik, and Zhou, 2014) calls for an integration between the creativity and innovation literatures. The creativity stage of the process refers to idea generation, whereas the innovation stage refers to the introduction of ideas. Although we cannot measure the successful introduction of ideas, EII can give us a sense of an agent's propensity to act on an idea. Agents with higher confidence in their ideas are also more likely to act on them (Hélie and Sun, 2010a). The ICL is continuous, and correspondingly, if the ICL barely crosses the threshold, the creative output is produced, but it does not lead to an intense "Aha!" experience. In contrast, when the ICL suddenly becomes very high a very intense insight experience can result (which can result in bold and confident action). In the Schumpeterian sense (Schumpeter, 1928, 1942), for creativity to be meaningful, it must be about more than just *seeing* beyond the proximate. It also requires aggressive, bold, and confident qualities (Kirzner, 1999). As such, for economic agents to recognize opportunities as valuable for themselves, and therefore to act on these opportunities, may require intense moments of insight (McMullen and Shepherd, 2006). How paradoxical tensions affect action on creative ideas is an avenue for future research.

Limitations of the Current Study and Possible Directions of Future Research

Like in all other simulation studies, operationalizing the complexity of human cognition and behavior using a computer reduces external validity. Nevertheless, the use of simulations allows for new insights and has therefore been widely encouraged (Besold, Schorlemmer, and Smaill, 2015; Gavetti, Levinthal, and Ocasio, 2007; Powell, Lovallo, and Fox, 2011). We utilize a computational model from cognitive science to address an empirically challenging phenomenon in organizational science. This simulation allows us to observe the effects of a range of degrees of paradoxical tensions on creativity as well as the underlying mechanisms responsible for this relationship. We attempt to validate our simulation by accounting for data from previously published work on the relationship between paradoxical frames and creativity.

The results reveal an interesting and, as of yet, empirically unobserved relationship. We therefore provide a new perspective on an existing theory. Future research on paradox and creativity would benefit from different methodological approaches, such as field observations of how paradox affects creative performance of strategic leaders – especially over different contexts of time and space. Such studies would require the classification of paradoxical tensions as well as individual levels of integrative complexity. Future research should also address the effects of paradoxical tensions at different levels of analysis (e.g., team, organization). Future research in this direction could provide significant insights into organizational design, strategic reactions to contradictory demands, and hiring decisions.

Another limitation is that we based our study on previous research's findings that paradoxical tensions increase integration and differentiation, which increase creativity. With our discovery of a more fine-grained relationship between on the one-hand, integration and differentiation and, on the other hand, creativity, we believe that more fine-grained research into the effect of paradoxical tensions is also warranted. Not all paradoxes will be alike in intensity, relevance, and salience to a given decision maker. Future work should attempt to distinguish between different types of paradox, such as social and business tensions (Gonin, Besharov, and Smith, 2013). In addition, some paradoxes may be more salient to specific individuals than are others. One can imagine that an ideologically driven social entrepreneur would be more deeply affected by the paradox of fulfilling his ideological goals and the economic survival of his social venture than would a commercial entrepreneur facing a situation where she needs to work in a context of seemingly contradictory goals, such as individual responsibility and team solidarity. While the current study focuses on refining the picture of how paradoxical frames may *in general* influence creativity through integration and differentiation, similar work remains to be done on the effects of *specific* paradoxical frames on integration and differentiation.

Conclusion

We began our study by focusing on the integration and differentiation conditions under which paradoxical frames enhance creativity. Utilizing a computational simulation of EII, we model the creativity process and find that the relationship between paradoxical frames and creative performance is complex and non-monotonic. In fact, we find that the relationship between paradoxical frames and creativity is parabolic. Our findings reveals this is the result of increased integration, which leads to uncertainty in the presence of more alternatives. In other words, we find creativity increases with greater differentiation and integration, but only up to a point. After such a point, higher integration reduces creative performance. We also find that creativity may be more sensitive to changes in differentiation than it is to changes in integration. Our findings enhance current theory by suggesting that the relationship between paradoxical tensions and creative performance is more nuanced than previously thought. Our findings also suggest ways in which the organizational paradoxes may be harnesses to increase creativity.

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APPENDIX A

MATHEMATICAL EXPOSITION OF EII

The general structure of the model resulting from EII (implemented in the Non-Action-Centered Subsystem of CLARION; Sun, 2002) is shown in Figure A1. The model is composed of two major modules, representing explicit and implicit knowledge respectively. These two modules are connected through bidirectional associative memories (i.e., the **E** and **F** weight matrices; Kosko, 1988). In each trial, the task is simultaneously processed in both modules, and their outputs (response activations) are integrated in order to determine a response distribution. Once this distribution is specified, a response is stochastically chosen and the statistical mode of the distribution is used to estimate the ICL. If this measure is higher than a predefined threshold, the chosen response is output; otherwise, another iteration of processing is done in both modules, using the chosen response as the input.

In the model, explicit processing is captured using a two-layer linear connectionist network while implicit processing is captured using a non-linear attractor neural network (*NDRAM*: Chartier & Proulx, 2005). The inaccessible nature of implicit knowledge may be captured by distributed representations in an attractor neural network, because units in a distributed representation are capable of accomplishing tasks but are less individually meaningful. This characteristic corresponds well with the relative inaccessibility of implicit knowledge. In contrast, explicit knowledge may be captured in computational modeling by localist representations, because each unit in a localist representation is more easily interpretable and has a clearer conceptual meaning. This characteristic captures the property of explicit knowledge being more accessible and manipulable. This difference in the representation of the two types of knowledge leads to a dual-representation, dual-process model.

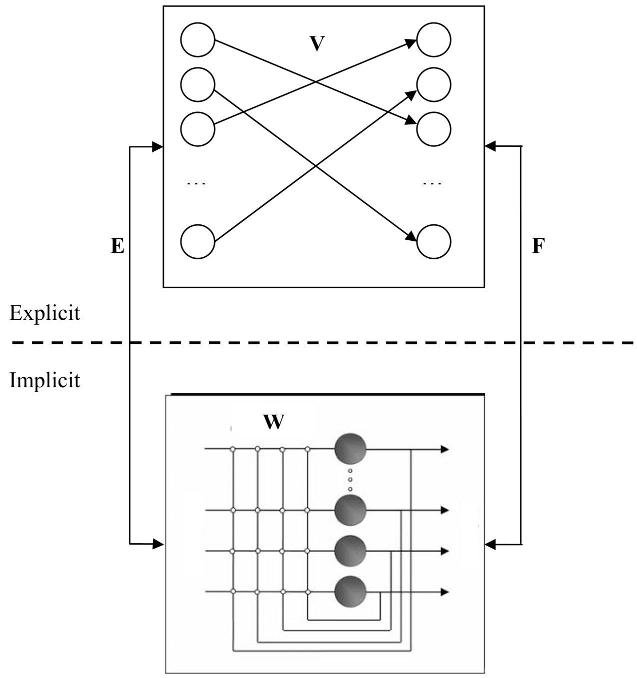


Figure A1. General architecture of the connectionist model. The model is implemented in the Non-Action-Centered Subsystem of CLARION (Sun, 2002).

Specifically, explicit knowledge is localistically represented in the top level using binary activation. The left layer in Figure A1 (denoted **x**) is composed of *n* units while the right layer (denoted **y**) is composed of *m* units. These layers are connected using the binary weight matrix **V**, and the information is transmitted using the standard weighted sum (dot product, i.e., $\mathbf{y} = \mathbf{NVx}$, where **N** is a diagonal matrix normalizing the activation of **y**).[4]

In the bottom level, implicit knowledge is represented using *r* bipolar units (denoted **z**). Specifically, $\mathbf{z} = \mathbf{t}_1 + \mathbf{t}_2$, where $\mathbf{t}_1$ represents the first *s* units in **z**, which are connected to the left layer in the top level using the **E** weight matrix. Meanwhile, $\mathbf{t}_2$ represents the remaining $r - s$

[4] In the model, all the weight matrices are learned using Hebbian learning. This type of learning has the advantage of psychological and biological plausibility. The **V**, **E**, and **F** weight matrices are learned using regular Hebbian learning (i.e., the outer matrix product). The bottom-level weight matrix (**W**) is learned using a contrastive Hebbian learning rule (Chartier & Proulx, 2005). More details can be found in the appendix of Helie & Sun (2010a).

units in **z**, which are connected to the right layer in the top level using weight matrix **F**. In words, the **E** and **F** weight matrices are used to 'translate' explicit knowledge into implicit knowledge (i.e., 'implicitation') and vice-versa (i.e., 'explicitation').

Bottom-level activation (**z**) is modified through a settling process using the NDRAM transmission rule:

$$\mathbf{z}_{[t+1]} = f(\mathbf{W}\mathbf{z}_{[t]}), \qquad f(z_i) = \begin{cases} +1 & , z_i > 1 \\ (\delta+1)z_i - \delta z_i^3, & -1 \le z_i \le 1 \\ -1 & , z_i < -1 \end{cases} \quad \text{(A1)}$$

where $\mathbf{z}_{[t]} = \{z_1, z_2, \ldots, z_r\}$is the bottom-level activation after t iterations in the network, **W** is the bottom-level weight matrix, and $0 < \delta < 0.5$ is the slope of the transmission function. This settling process amounts to a search through a soft constraint satisfaction process, where each connection represents a constraint and the weights represent the importance of the constraints. Note that it was estimated psychologically that each iteration in this network takes roughly 350 ms of psychological time.

Once the response activations have been computed in both levels, they are integrated using the *Max* function:

$$o_i = Max\left[y_i,\ \lambda(k_i)^{-1.1}\sum_{j=1}^{r} f_{ji}z_j\right] \quad \text{(A2)}$$

where $\mathbf{o} = \{o_1, o_2, \ldots, o_m\}$ is the integrated response activation, $\mathbf{y} = \{y_1, y_2, \ldots, y_m\}$ is the result of top-level processing, λ is a scaling parameter specifying the relative weight of bottom-level processing, k_i is the number of nodes in the bottom level (in **z**) that are connected to y_i ($k_i \le r - s$), and $\mathbf{F} = [f_{ij}]$ is a weight matrix. The integrated response activation is then transformed into the Boltzmann response distribution:

$$P(o_i) = e^{o_i/\alpha}\left(\sum_j e^{o_j/\alpha}\right)^{-1} \qquad \text{(A3)}$$

where α is a noise parameter (i.e., the temperature). Note that low noise levels tend to exaggerate the probability differences, which lead to a narrow search of possible responses and favors stereotypical responses. In contrast, high noise levels tend to minimize the probability differences, which leads to a more complete search of the response space.

A response is stochastically chosen based on the response distribution (A3) and the statistical mode of the distribution is computed to estimate the ICL. This measure represents the relative support for the most likely response (which may or may not be the stochastically selected response). In the current model, the chosen response is output if the ICL is higher than threshold ψ. However, if the ICL is smaller than ψ, the search process continues with a new iteration using the chosen response to activate the left layer ($\mathbf{x} = \mathbf{V}^T\mathbf{o}$; $\mathbf{z} = \mathbf{E}\mathbf{x}$). The algorithm specifying the complete process is summarized in Table A1.

Table A1: Algorithm of the Connectionist Model

1. Observe the current state of the environment;
2. Compute the response activations;
3. Compute the integrated response activation and the resulting response distribution;
4. Stochastically choose a response and compute the statistical mode of the response distribution:
    a. If the mode is higher than ψ, output the response;
5. Else, if there is time remaining, go back to step 2.

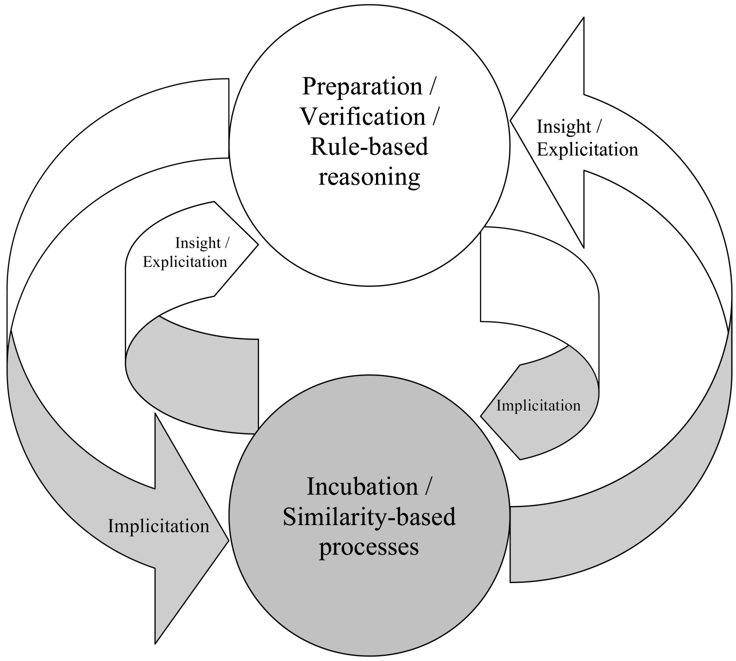


Figure 1. Information flow in the EII theory. The grey sections are implicit while the white sections are explicit.

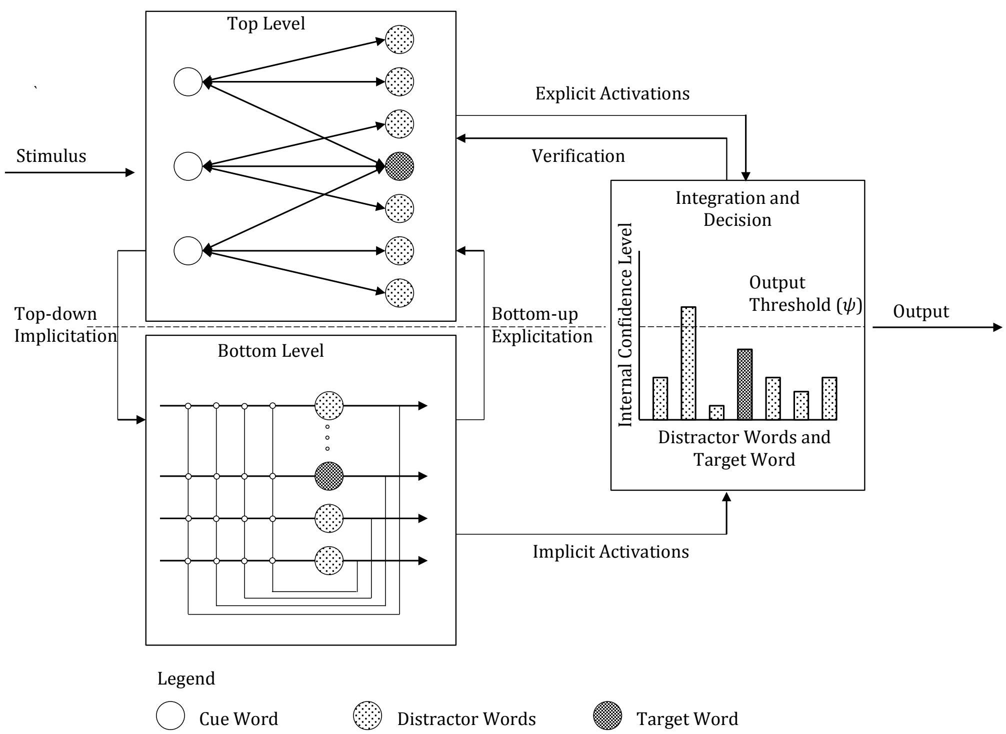
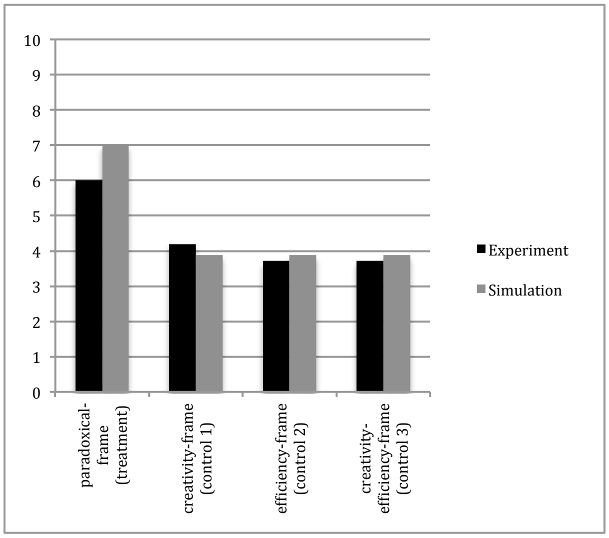


Figure 2. Graphical Representation of the Simulation Process for the Remote Association Task Experiment.

(a)



(b)

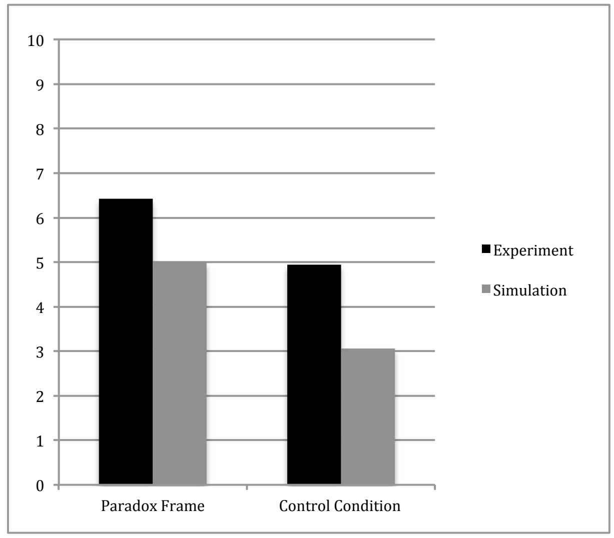


Figure 3. Number of RAT problems correctly solved by condition. Simulated and human experiment data from Miron-Spektor, Gino, Argote's (2011) study 1 (a) and study 2 (b).

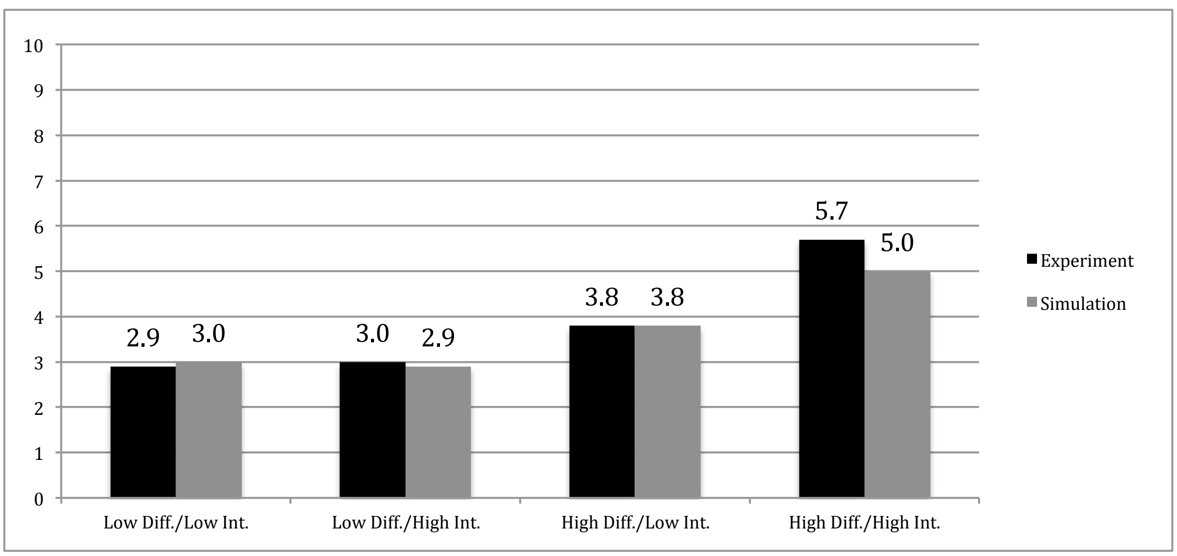


Figure 4. Comparison of correct RAT solutions by condition between simulated results and human experiment data in study 4.

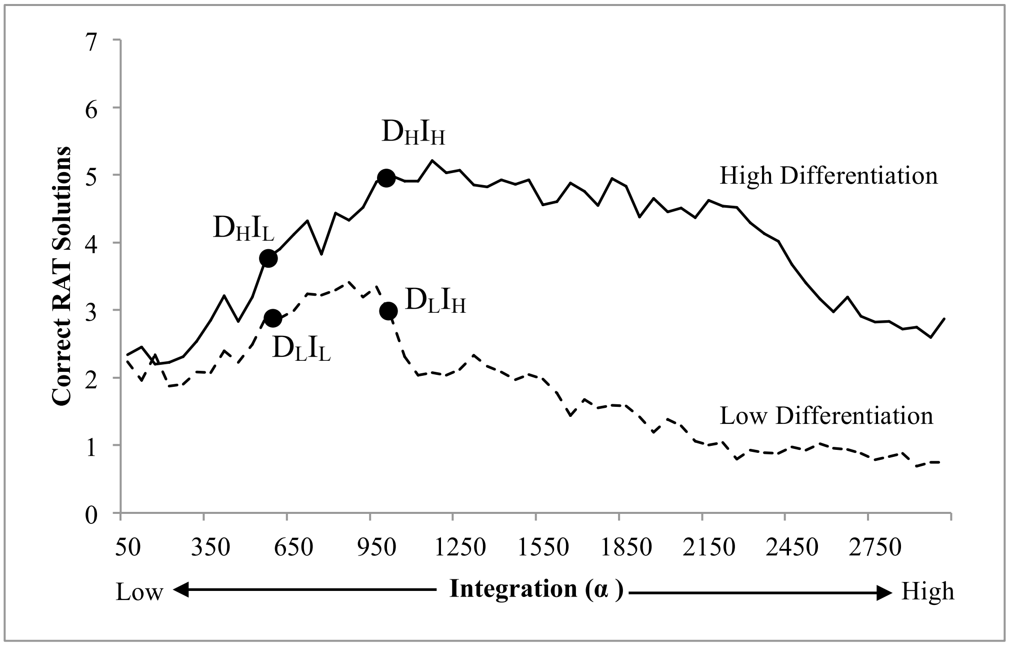


Figure 5. Effects of integration (α) on number of correct RAT solutions.

Note. High Differentiation (ψ = 0.25), Low Differentiation (ψ = 0.45)

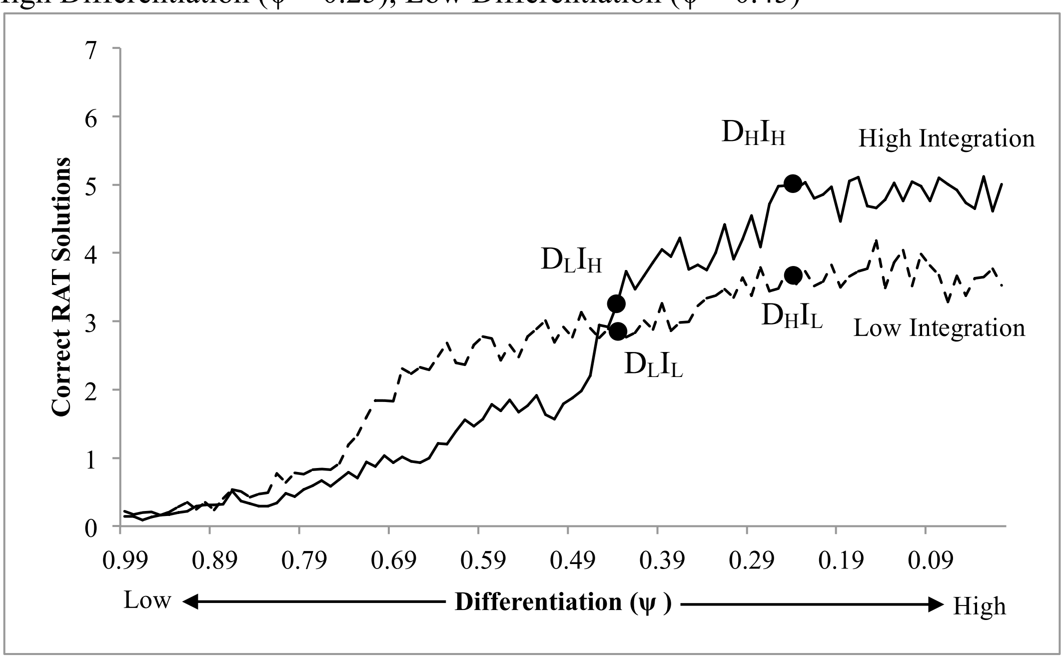


Figure 6. Effects of differentiation (ψ) on number of correct RAT solutions.

Note. High Level of Integration (α = 1,000), Low Level of Integration (α = 550).

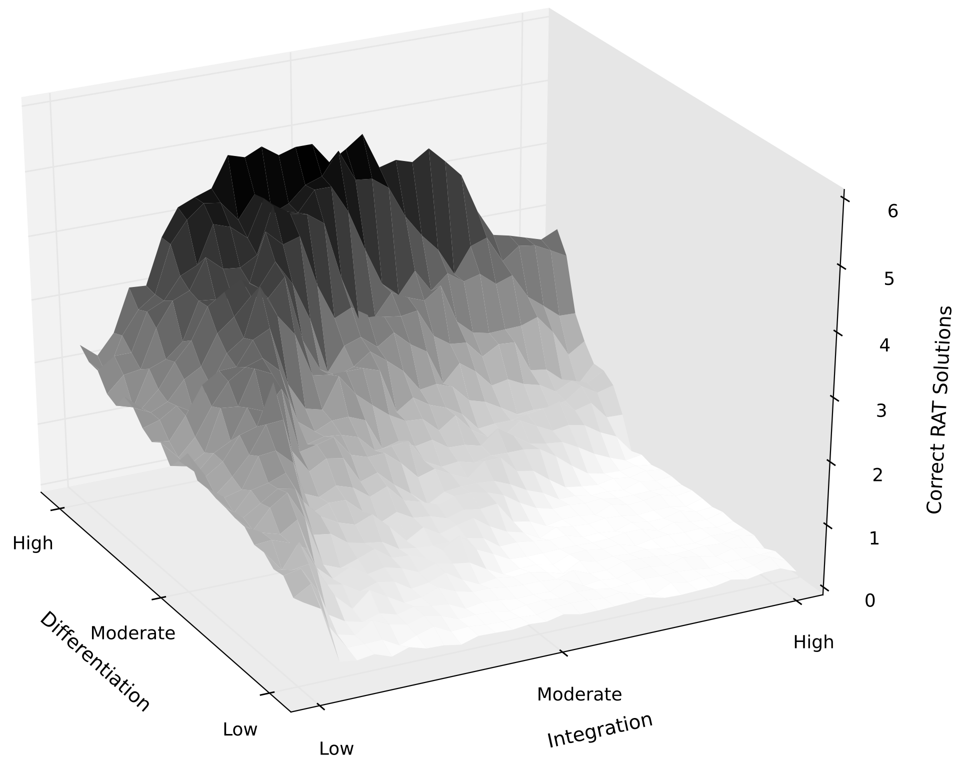


Figure 7. Non-monotonic effect of differentiation and integration on number of correct RAT solutions