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ERRORS IN CREATIVE PROBLEM-SOLVING: IDENTIFY, DELIBERATE, AND REMEDIATE

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ERRORS IN CREATIVE PROBLEM-SOLVING: IDENTIFY, DELIBERATE, AND REMEDIATE

A THESIS APPROVED FOR THE

DEPARTMENT OF PSYCHOLOGY

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Abstract

It is often assumed creative performance is error free. Even a cursory inspection of eminent, creative, individuals indicates errors permeate creative efforts. In the present effort, we examine the impact of error management on creative problem-solving. Undergraduates, 136 in all, were asked to work through 10 potential problem solutions where half the solutions evidenced errors and half did not. Participants were asked to identify potential errors, deliberate on these errors, and remediate, or fix, errors prior to providing solutions to a problem calling for creative thought. It was found the number of errors correctly identified and the quality of error remediation was positively related to the quality, originality, and elegance of problem solutions. More extensive deliberation, however, was found to be especially important for production of original problem solutions. The implications of these observations for understanding the importance of error management in creative problem-solving are discussed.

Key words: creativity, innovation, performance, errors, error management

Errors in Creative Problem-Solving: Identify, Deliberate, and Remediate

Eminent achievement in many fields is held to depend on the production of viable new ideas (Mumford, Connelly, Scott, Espejo, Sohl, Hunter, & Bedell, 2005). Production of viable new ideas, however, is held to be based on creative thought or the production of original, high quality, and elegant solutions (Besemer and O'Quinn, 1999; Christiaans, 2002, Weisberg, 2015) to a certain class, or type, of problem – specifically, novel, complex, ill-defined, or poorly structured, problems (Mumford & Gustafson, 2007). Solutions to novel, complex, ill-defined problems, of course, do not unfold smoothly. Errors, potentially many errors, occur along the way to problem solution.

Indeed, an examination of the careers of most creative people provide ample evidence bearing on this point. As Pray (2008) has pointed out, correction of assembly errors by Watson and Crick was a key step in identifying the structure of DNA. Frederick Taylor's development of standard operating procedures, a key principle in modern management, was based on an attempt to eliminate operation errors in mechanical operations (Kanigel, 2005). Carlson and Gorman (1992) note the Wright brothers made many errors, errors they learned from, as they sought to develop powered flight.

Other examples of this sort might be cited. These illustrations, however, make our basic point. Error is evidenced in creative work and creative problem-solving. Although error is embedded in creative problem-solving efforts, the impact of errors on creative performance and the ways people work with these errors has received little attention (Hammond, Farr, & Sherman, 2011). Accordingly, our intent in the present study was twofold. First, we hoped to show certain error identification and remediation activities contributed to the production of more creative problem solutions. Second, we hoped to show that thinking about errors, and thinking

about errors in greater depth, is integral to the production of more original solutions to the kinds of problems that call for creative thought. Before turning to these issues, however, it would seem necessary to consider what we know about errors and how errors occur in creative problem-solving.

Errors

Although failure may be a consequence of error, failure, including failures in creative problem-solving, may occur for many reasons. Perhaps people may lack access to critical information, or, alternatively, the goals prior to problem-solving may be inappropriate. Thus failure is context dependent. Errors, however, are held to be a property of an individual's actions, although cross-level effects (e.g., group, team) may operate (Lei, Naveh, & Novikov, 2016), where the actions of the individual lead to an undesirable gap between expected and actual performance (Zhou & Olivera, 2006).

As might be expected based on this definition, many types of errors may be observed in human performance (Norman, 1984; Rasmussen, 1983; Reason, 1990). For example, Frese and Zapf (1994) note errors may arise from movement, habit, omission, recognition, memory, judgement, goal setting, and mapping. Rizzo, Bagnara, and Visciola (1987) have argued that errors may arise from slips, inaccurate task execution, inappropriate rule application, or inadequate use of knowledge.

Although errors might arise from multiple sources, a key question arises of some importance with respect to understanding the impact of errors on human performance. Can people recognize, or detect errors, they have made (Hoffman & Frese, 2011)? Allwood (1984) conducted a study examining people's ability to detect errors made in solving two statistical problems. Think aloud protocol data was obtained as people worked through these problems, and

incidents of error recognition were identified. It was found that participants could detect errors. Two strategies, in fact, were found to be commonly used in error detection. First, people could identify errors vis a vis experiential representations of errors made in past performance. Second, people could identify errors based on a mismatch between performance expectations and actual outcomes. It was found, moreover, that people who were more skilled in identifying errors, typically, produced better problem solutions.

People's ability to identify errors raises questions about how people go about identifying errors. Cowan (1986) has argued error identification is ultimately based on identification of discrepancies between expected and actual performance. Indeed, discrepancies might be identified based on either experience matching or analysis of performance – the two strategies identified by Allwood (1984). Cowan argued, however, that a discrepancy may, or may not, be important in identifying, or detecting, an error. Instead he argued that error detection requires attention to the discrepancy, identification of the nature of the discrepancy, interpretation as to the significance of the discrepancy, and, if an error is identified, an attempt to remediate this error. Thus Cowan (1986) holds errors must be identified, appraised, or deliberated on, and, subsequently, remediated.

Identification, deliberation, and remediation, however, imply that error identification, deliberation, and remediation might also provide a basis for learning (Rasmussen, 1990). In fact, Keith and Frese (2005, 2008) have provided evidence indicating that teaching people strategies for accepting and learning from errors, error management training, is a more effective instructional strategy for improving task performance than error avoidance training. In this regard, however, the findings of the Keith and Frese (2008), in a meta-analysis, are especially noteworthy. They found that error management instruction is especially effective when transfer

of training to actual job performance is used to evaluate the instructional program and the task performance is structurally distinct from training. In other words, the conditions contributing to creative task performance where unfamiliar, novel, problems are to be solved.

Creativity and Errors

In fact, a variety of evidence has been provided which indicates errors also arise in creative problem-solving efforts. Mumford, Blair, Dailey, Lertiz, and Osburn (2006) have examined how various cognitive biases that might influence effective execution of key processes, problem definition, information gathering, concept selection, conceptual combination, idea generation, idea evaluation, implementation planning, and adaptive monitoring (Mumford, Mobley, Reiter-Palmon, Uhlman, & Doares, 1991) held to be called for in creative problem-solving. They argued biases arising from use of simplification strategies, complication strategies, capacity limitations, expertise, and idea evaluation or judgement, all might lead to errors in peoples' creative problem-solving efforts.

Some initial evidence pointing to the impact of errors on creative problem-solving efforts has been provided in a study by Blair and Mumford (2007). In this study, participants, undergraduates, were asked to evaluate ideas being considered for funding by a foundation. Participants were asked to compare pairs of ideas and recommend which idea in the pair should be funded. Notably, idea pairs differed with respect to select attributes. It was found people errored in idea evaluation because they discounted original, risky ideas which were time consuming – although original, risky, time consuming ideas are those most likely to lead to creative problem solutions.

In another study of errors made in idea evaluation, Licuanan, Dailey, and Mumford (2007) again examined errors in the idea evaluation process. In this study, participants,

undergraduates, were asked to evaluate the originality of six marketing campaigns where the level of idea originality was varied. It was found participants discounted ideas of high originality. However, this error, discounting original ideas, was reduced when people were required to actively analyze ideas – analysis induced through a report writing manipulation.

Errors, however, are not unique to the idea evaluation process. For example, Ward, Patterson, and Sifonis (2004) asked undergraduates to draw aliens. Notably, when given instructions to think about life on earth, less creative drawings of aliens were obtained than when they were asked to think abstractly. Thus, the framing of the task led to error on this conceptual combination problem. Along somewhat different lines, Mumford, Baughman, Threlfall, Supinski, and Costanza (1996) have shown errors may arise in problem definition due to an undue focus on goals as opposed to the procedures and constraints relevant to problem definition.

Taken as a whole, these studies all indicate that errors might occur in executing all of the processing activities required for creative problem-solving. The next question to arise, however, is whether analysis of errors has value in changing people's performance when working on creative problem-solving tasks. Some initial evidence along these lines has been provided in a study by Robledo, Hester, Peterson, Barrett, Day, Hougen, and Mumford (2012). In this study, participants were asked to assume the role of a new principal asked to lead an experimental secondary school. Participants were to provide written plans for leading this school which judges appraised for quality, originality, and elegance. Prior to starting work on this task, however, participants were asked to illustrate their mental models for understanding secondary schools. They were also asked to, again, illustrate their mental model for understanding secondary schools after completing a set of training exercises.

The training provided before starting work on the educational leadership problem was a form of error management training. Here participants were asked to complete up to four self-paced instructional modules where they were trained in various error management strategies. The four training modules participants were asked to complete included 1) future consequences – think about errors that might happen in the future as a result of earlier error, 2) social consequences – think about how errors might effect different stakeholder groups, 3) controllability – think about whether an error would be under your control, and 4) criticality – think about how large an effect an error might have in attaining your objective.

Three key findings emerged from this study. First, exposure to error management training, all training modules, resulted in the production of more original and more elegant problem solutions. Second, exposure to only the criticality module resulted in production of higher quality solutions on this creative problem-solving task. Third, exposure to error management training resulted in acquisition of stronger post instruction mental models for conceptualizing the task at hand.

These findings are noteworthy because they suggest that errors need not always disrupt creative problem-solving. Instead, if people actively think about errors and work with errors in creative problem-solving, more creative problem solutions may emerge. Of course, people can not think about errors in creative problem-solving if no errors have been identified. Given our foregoing observations however one would expect, that those who identify errors in scenarios calling for creative problem-solving would be more likely to produce creative problem solutions. This observation, in turn, led to our first hypothesis.

Hypothesis 1: Correct identification of actual errors in scenarios calling for creative problem solutions will result in the production of creative problem solutions of higher originality, higher quality, and higher elegance.

What should be recognized in this regard, however, is that it may not be necessary simply to identify actual errors. If people in creative problem-solving actively think about potential errors, they may process more deeply the problem-solving scenario at hand. And, greater depth in processing information about problem scenarios may result in production of creative problem solutions evidencing greater quality, originality, and elegance. Accordingly, a second hypothesis seemed indicated.

Hypothesis 2: Identification of more errors in problem scenarios, regardless of whether the error is or is not present, will result in production of creative problem solutions of higher originality, higher quality, and higher elegance.

Remediation and Deliberation

Of course, it is not enough simply to identify errors. Creative problem-solving is a form, albeit a complex form, of human performance. As a result, one would expect that attempts to improve problem solutions by remediating, or fixing, identified errors, will also prove of some importance. In fact, studies by Gibson and Mumford (2013) and Lonergan, Scott, and Mumford (2004) provide some indirect support for this proposition.

The Gibson and Mumford (2013) study examined the value of criticism by others of creative ideas. In this study, undergraduates were asked to assume the role of a marketing director of a clothing firm and provide an advertising campaign for a new line of clothing. Campaign descriptions were appraised by judges for quality, originality, and elegance. Prior to

preparing their campaigns, however, participants were presented with a set of candidate ideas they were asked to critique. It was found that those who provided a limited number of deep criticisms of candidate ideas produced the most creative advertising campaigns. Because criticism, at least indirectly, suggests an attempt to remediate errors, this study points to the potential importance of error remediation in creative problem-solving.

Some further evidence along those lines is provided in the Lonergan, Scott, and Mumford (2004) study. In this study, participants, again undergraduates, were asked to assume the role of a manager in an advertising firm evaluating ideas for a marketing campaign for a creative new product – the 3D holographic television. Ideas presented were varied with respect to either quality or originality based on the findings obtained in an earlier study by Redmond, Mumford, and Teach (1993). The instructions provided as participants worked on this task requested that ideas be evaluated with respect to either innovation potential or operating efficiency. It was found the most creative campaigns emerged when participants evaluated high quality ideas for innovation potential *or* original ideas for operating efficiency. Thus, in idea evaluation, a compensatory appraisal is employed – compensation that attempts to remediate perceived deficiencies, potentially errors, in creative ideas.

The findings obtained in the Gibson and Mumford (2013) and Lonergan, Scott, and Mumford (2004) studies suggest remediation, improvement, of creative solutions contributes to the production of more creative problem solutions. Although these studies did not directly examine the value of remediating errors, it is not a leap to suggest that remediation of identified errors will also contribute to creative problem-solving. Hence our third hypothesis:

Hypotheses 3: Attempts to remediate identified errors will contribute to the production of creative problem solutions evidencing greater originality, quality, and elegance.

Of course, to remediate errors, one must think about the nature and implications of the error identified. Put differently, this observation suggests that people must deliberate on errors or think about the errors they have identified in some depth. In fact, the work of Gollwitzer and his colleagues (Fujita, Gollwitzer, & Oettingen, 2007; Gollwitzer & Bayer, 1999; Gollwitzer, Heckhausen, & Steller, 1990) suggests that deliberation contributes to performance where people are asked to work on complex, real-world, problem-solving tasks. Still other work by Purser, Pasmore, and Tenkasi (1992) indicates that deliberation is critical to performance in new product development teams.

Somewhat more direct evidence bearing on the importance of deliberation may be found in a study by Marcy and Mumford (2007). In this study, participants, undergraduates, were asked to provide solutions to six social innovation problems – three problems drawn from the business domain and three problems drawn from the educational domain, all of which called for creative thought. Judges were asked to appraise the quality, originality, and elegance of the resulting problem solutions. Notably, deliberation was induced through manipulations where participants were asked, or not asked, to forecast the downstream implications of their problem solutions and/or to think about the implications of their problem solutions for stakeholders "working" in other related institutions. Prior to starting work on these problem-solving tasks, however, participants were also given training in causal analysis skills. Not only was it found that causal analysis skills contributed to the production of more creative problem solutions, but the impact of this instruction was greater when participants worked under conditions where deliberation was required.

Deliberation on errors, however may have rather complex effects on people's creative problem-solving. On the one hand, deliberation on identified errors may lead people to consider

multiple, alternative, paths to a problem solution. As a result of considering multiple, alternative, paths to a problem solution, we would expect deliberation on identified errors to result in the production of more original problem solutions. By the same token, in considering multiple alternative paths to a problem solution, the complexity, and difficulty, of the problem-solving effort is likely to increase. Increased complexity and difficulty, however, may make it more difficult for people to craft an elegant or high quality problem solution. Accordingly, our final two hypotheses, seemed indicated:

Hypothesis 4: Deliberation on identified errors will result in the production of more original problem solutions.

Hypothesis 5: Deliberation on identified errors will result in the production of less elegant problem solutions, and problem solutions of lesser quality.

Method

Sample

The sample used to test these hypotheses consisted of 136 undergraduates attending a large southwestern university. Participants were recruited from introductory psychology classes providing extra-credit for participation in experimental studies. Students interested in obtaining extra credit reviewed a website providing a brief, one paragraph, description of each available study and they selected the study, or studies, in which they wished to participate. The 31.6% men and 68.4% women who agreed to participate in the present study were on average 18.7 years old. Their academic ability, as indexed by scores on the academic achievement test, lay a quarter standard deviation above freshmen matriculating at four-year institutions.

General Procedures

Participants were recruited to participate in what was purported to be a study of problem-solving performance. During the first half hour of the three-hour study, participants were asked to complete a set of timed covariate controls. Over the course of the next hour and a half, participants were asked to work on the experimental task. During the final hour of the study, participants were asked to complete a battery of untimed covariate control measures.

The experimental task presented a novel, complex, ill-defined creative problem-solving task drawn from Gibson and Mumford (2013). On this task, participants are asked to assume the role of a mid-level marketing manager working for a specialty apparel firm. After reading through a description of the firm and its current goals, expansion into the southern clothing market, they were presented with a summary of market research bearing on the firm. The market research provided the known, established, facts bearing on any marketing plan. Subsequently, participants were presented with ten ideas for this marketing campaign provided by other managers working in the firm. Participants were asked to review these ideas, providing written responses to a set of probe questions, and then provide a written plan for the marketing campaign. Judges appraised the quality, originality, and elegance of the final written marketing plans provided (Besemer & O'Quin, 1999; Christiaans, 2002).

Participants were presented with a set of ten ideas provided by other managers. After reading through these ideas, they were asked to respond to a series of probe questions. These problems asked participants, in all conditions, to summarize the idea presented. In the experimental conditions, participants were presented with additional probe questions where they were asked to identify any errors evident in the idea presented, describe the potential consequences of these errors, and describe how they would remediate, or fix, these errors. Half

the scenarios presented had errors embedded in them where errors were specified based on prior research on marketing errors by Korte (2003). Written answers to these probe questions were appraised by judges to evaluate their performance in deliberation on, and remediation of, identified errors.

Controls

The first set of covariate control measures were intended to take into account the known effects of intelligence, divergent thinking, and expertise on creative problem-solving (Vincent, Decker, & Mumford, 2002). The intelligence test participants were asked to complete was the verbal reasoning measure drawn from the Employee Aptitude Survey. Each item, in this 30-item measure, presents a set of facts bearing on a problem and asks people to indicate whether a subsequent conclusion is true, false, or uncertain. This verbal reasoning test produces retest reliabilities above .80. Evidence for the validity of the test as a measure of intelligence has been provided by Grimsley, Ruch, Warren, and Ford (1985) and Ruch and Ruch (1980).

To measure divergent thinking, participants were asked to complete Merrifield, Guilford, Christensen, and Frick's (1962) consequences measure. This particular test was used to measure divergent thinking based on its relevance to the experimental task. The consequences test presents five unlikely such as "What would be the consequences if people no longer wanted or needed to sleep". People are asked to list as many consequences as they can think of to these five questions under a ten minute time limit. When scored for fluency, or the number of consequences listed, this measure yields internal consistency coefficients above .70. Evidence bearing on the construct validity of this measure has been provided by Merrifield et al. (1962) and Vincent, Decker, and Mumford (2002). It is of note fluency scores were used, as opposed to originality scores, due to the use of divergent thinking as a covariate control.

In addition to these two timed measures, expertise was assessed using Gibson and Mumford's (2013) measure of marketing expertise. This untimed measure presents background data questions (Mumford & Owens, 1987) examining engagement in advertising, or marketing, evident earlier in people's lives – for example "How often have you discussed current advertisements with your friends" or "How often have you thought about how you could make advertisements better." These self-report items are scored on a five point scale reflecting the frequency, or intensity, of the behavior. The resulting scale produces internal consistency coefficients about .70. Gibson and Mumford (2013) have provided evidence bearing on the validity of this measure of marketing expertise. In addition to this measure of marketing expertise, task specific expertise was assessed using a five item knowledge test administered along with the other untimed covariates. This knowledge test presented a series of five questions bearing on participants knowledge of the firm. When scored for production of correct answers, internal consistency coefficients above .70 are obtained. Because all questions directly mapped to the content of the experimental task, evidence is available for the content validity of this measure.

Because participants were asked to provide plans for their marketing campaigns, they were also asked to complete Marta, Leritz, and Mumford's (2005) measure of planning skills. This measure presents a series of business scenarios. After reading through each scenario, participants were presented with a series of five questions, where each question bearing on a key planning skill (e.g., identification of downstream consequences) and participants were asked to indicate 3 or 4 potential answers to this question, from 6 to 12 potential responses, where responses were scored for effective application of relevant planning skills. This measure yields

split-half reliability coefficients in the .80s. Marta, Lertiz, and Mumford (2005) have provided evidence for the construct and predictive validity of the measure.

The experimental task at hand also required some investment of cognitive resources. Accordingly, participants were asked to complete Cacioppo and Petty's (1982) need for cognition scale. This 18-item scale presents behavioral statements examining engagement in cognitive activities such as "I prefer complex to simple problems" or "I prefer my life to be filled with problems I must solve". Participants rate, on a 5-point scale, the extent to which they agree with these statements. This scale yields internal consistency coefficients about .80. Marcy and Mumford (2007) and Osburn and Mumford (2006) have provided evidence for the ability of scores on this measure to predict creative performance.

The final covariate measures participants were asked to complete was intended to provide a global assessment of personality. Here participants were asked to complete Gill and Hodgkinson's (2007) measure of openness, neuroticism, agreeableness, conscientiousness, and extraversion. This measure presents people with 100 adjectives – for example, artistic, critical, kind. People are asked to indicate, on a 9-point scale, how accurate those adjectives are in describing them. The resulting scales for measuring these five personality characteristics produce internal consistency coefficients above .80. Gill and Hodgkinson (2007) have provided evidence for the validity of these scales as measure of these "Big Five" personality characteristics.

Experimental task

The experimental task asked participants to assume the role of a mid-level marketing manager working for the Charamousse clothing firm. In this role, they were asked to produce a written marketing campaign which would be presented to senior management. After reading through this general introduction, participants were presented with a general history of the firm.

This background material noted the firm had been founded in 1998 with the intention of providing original, unique, clothing through sustainable production practices. It was noted each shirt produced by the firm was based on a limited run, individually numbered, so buyers had a unique product. The firm was said to have 14 stores across the mid-west typically in malls and high profile locations in metropolitan areas. All stores were in refurnished, renovated spaces, in keeping with the firm's vision.

Following this description of the firm's history the current situation confronting the firm was described. It was noted the firm's revenue had grown by "double-digits" in the early 2000's until 2015 due to high profile celebrity "converts". Since 2015, firm growth had slowed. To address this issue, the firm had decided to expand its operations to a new market in the southern United States. It was then noted you had been recently hired to help the firm formulate this southern marketing campaign. To help on this task, you would be asked to review some marketing ideas already developed by the firm.

After reading through this introductory material, participants were presented with a summary describing the firm's extant markets. This marketing research summary indicated most buyers were upwardly mobile young adults who spend a sizeable portion of their income on clothes. The firm was well known in the mid-west but not the south. Competitors were other high end design firms. Most customers were college graduates earning some $60,000 per year with an interest in exercise - but yoga rather than weight training or sports. They were held to show more engagement in volunteer organizations. Similar firms were held to include Apple, drinks made by Odwalla, and hybrid cars. Figure one presents this market research summary.

Marketing Research

Customer Profile: Our average customer at Charamousse Clothing is an upwardly mobile extrovert with a passion for environmentalism. Our average customer spends a larger percentage of their budget on clothing than the average American consumer.

Age: The primary purchasers are between the ages of 25-39.

Brand Recognition/Power: we tend to be well known in the Midwest but in the South our name is relatively unknown.

Competitors: Our primary competitors tend to be designer clothing.

Education: Students have historically shown a strong interest in our products but our primary purchasers are typically college graduates. This finding could be due to the high price of our merchandise.

Gender: Charamousse clothing tends to be popular with both male and females, though historically 63% of our customers that ultimately purchase an article of clothing are female.

Income: The average income of the Charamousse customer hovers in the mid 60,000s. This income is notably higher than the national mean and shows that we tend to cater to more affluent clientele.

Interests and Activities: Our customers are much more likely than the general population to exercise regularly, typically through yoga or some other scheduled class rather than weight training or sports. They generally appreciate nature but spend little time outside. Lastly, the average customer tends to volunteer more than most Americans.

Location: To date we have been centered around Chicago so we cannot speak very much to a geographic location but we can say that our products tend to be in more metropolitan areas.

Similar Companies: Customers who buy Charamousse Clothing tend to also purchase products computers made by Apple, hybrid cars of any brand, and drinks made by Odwalla.

Figure 1. Charamousse market research summary

Once they had read through this background material, participants were presented with an email from the firm's senior vice president for marketing. It was noted that this firm had developed some initial ideas. The senior vice president, Colleen Anderson, requested they review these ideas and "identify any solution related errors you see in the proposed marketing ideas and explain how you would fix those errors". An attachment to this email provided an overview of errors. This attachment provided a definition of what was meant by the term errors. Example of

potential errors arising in new product production and approaches for fixing these errors were provided. Figure two illustrates this attachment.

Overview of Errors

Definition: Errors are defined as **mistakes in a solution, or missing information during the process of developing a solution.**

Problem: Produce a new product

Examples of how to identify errors:

Potential errors:

- Not considering the cost of production
- Not considering what customers want

Examples of how to analyze the consequences of the above errors:

Potential consequences:

- The company will over-produce and lose money
- The company will sell an undesirable product

Examples of how to fix the above errors:

Potential plans:

- Look at the average number of customers who shop at Charamouse and estimate a reasonable number for the location where the product will first be released
- Survey customers and ask what they would like to see from the company

Figure 2. Overview of errors

Subsequently, participants were presented with ten marketing ideas. Each idea scenario presented a basic idea in three or four sentences – team sales success results in employee prizes or plan a special event to attract both new and old customers. After reading through the general scenario, participants were presented with three "bullet point" actions, described in one sentence, that would be needed to execute this solution. For half the scenario's presented, errors occurred, one or more, in the three bullet pointed action recommendations. For the remaining half of the

scenario's, no error occurred in the bullet pointed actions. All errors presented in the five error scenarios were developed based on prior work by Korte (2003) describing key marketing errors including: 1) missing important causes, 2) unrealistic expectations of success, 3) failing to recognize complex interdependencies, 4) overlooking important alternatives, 5) selective information gathering, and 6) subjective information processing. Figure three presents a scenario where errors were evident in the "bullet points" and a scenario where no errors occurred.

Scenario with errors:
A major clothing competitor is developing a new product that will directly compete with Charamouse's best selling product. Their product is unusually appealing and cheaper than Charamouse's product. In developing a new marketing plan, here are some ideas reported to your senior manager:

- A manager will observe differences in the competitor's product and implement them into Charamouse's product **Overlooking important alternatives**
- They will hold a directed group meeting for implementing these differences into the current design **Missing important causes**
- Have new product ready for release within 2-3 months **Unrealistic expectations of success**

Scenario without errors:
Your senior manager is holding a contest to see which team creates the best new product. Each team must have these products designed by the holiday season. You want to assemble your team and get a head start on this product. In developing a new marketing plan, here are some ideas reported to your senior manager:

- Obtain quantitative data on consumer interests.
- Assemble project team for idea generation and sharing.
- Come up with reasonable timeline for product development and assign tasks to group members.

Figure 3. Example scenarios with and without errors

Scenarios were presented in a fixed order across all conditions to control for potential scenario effects. In addition, all participants, in all conditions, were asked to write a one or two

sentence summary describing each marketing idea. This step was taken to insure active processing of the ideas presented in each scenario.

Design and Manipulation

The design employed in the present effort was based on the assumption one cannot deliberate on, or attempt to remediate, errors unless errors have been identified. Thus, in the control condition, participants were asked simply to write their summary of each of the ten marketing ideas, and the email from the vice president for marketing made no mention of the need to identify errors. In all other conditions, participants were asked to identify errors in the email from the vice president for sales. After participants read a scenario in those conditions they were presented with an instruction which asked them to "list the errors you have identified in the space below." Participants were given 12 single spaced lines to list errors identified.

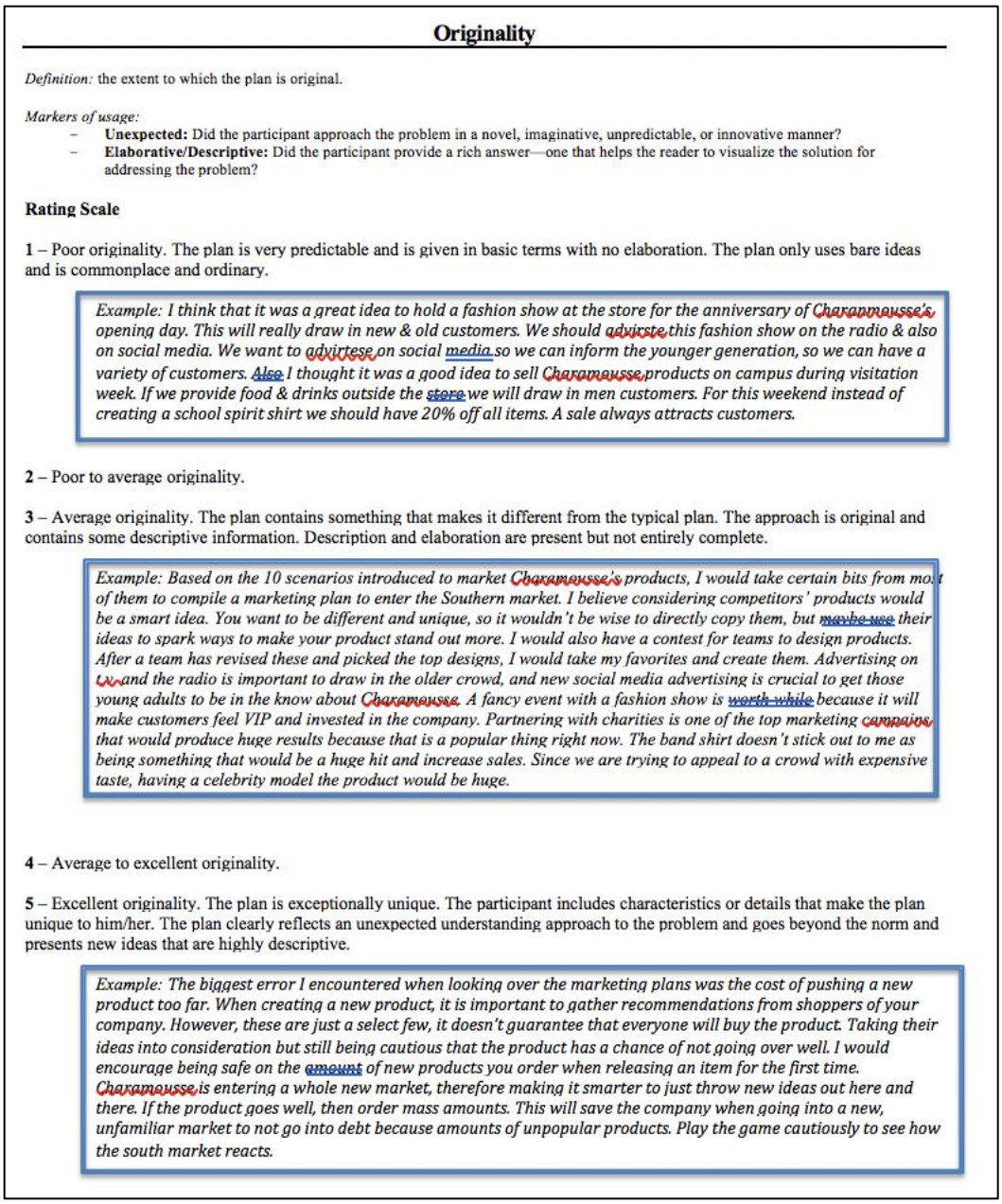
The next two manipulations occurred through probe questions presented following the probe question asking participants to list identified errors. In the deliberation condition, participants were, or were not, asked to provide a written response to the following question "Please think about the errors you have identified and describe the consequences of these errors in the space below." Participants were given 12 single spaces lines to describe these consequences. In the remediation condition, participants were, or were not, asked to "Take a minute to think about the errors you have identified and the consequences of these errors. Please explain how you would fix these errors in the space below." Participants were given 9 single spaced lines to answer this question. It is of note in the condition where both deliberation and remediation were requested, the deliberation question preceded the remediation question.

Dependent Variables

After participants had worked through the ten scenarios presenting various marketing ideas, they were presented with a second email from the senior vice president for marketing. This email requested that they formulate their own marketing plan for helping the Charamousse clothing firm move into the southern market. Participants were given two pages in which they were to provide a written description of their marketing plan.

In accordance with the observations of Besemer and O'Quin (1999) and Christiaans (2002) concerning the key attributes of creative problem solutions, obtained marketing plans were appraised for quality, originality, and elegance using a set of benchmark rating scales. Judges were asked to use benchmark rating scales in appraising marketing plans based on the observations of Redmond, Mumford, and Teach (1993) indicating greater reliability and better accuracy in evaluation of creative products made with respect to concrete examples.

These benchmark rating scales were developed in accordance with the procedures recommended by Redmond, Mumford, and Teach (1993). Initially, three judges were asked to rate a set of sample marketing plans for quality, originality, and elegance where 1) quality was defined as a complete, coherent, workable solution, 2) originality was defined as an unexpected well-elaborated solution, and 3) elegance was defined as a refined clever solution where solution elements fit together seamlessly. Based on these ratings, sample products with means near the high, mid, and low points of each scale which evidenced low standard deviations, disagreement across judges, were identified. Abstracts were then written reflecting key attributes of these problem solutions and used to provide scale anchors. Figure four provides illustrations of these benchmark rating scales.



Originality

Definition: the extent to which the plan is original.

Markers of usage:

- **Unexpected:** Did the participant approach the problem in a novel, imaginative, unpredictable, or innovative manner?
- **Elaborative/Descriptive:** Did the participant provide a rich answer—one that helps the reader to visualize the solution for addressing the problem?

Rating Scale

1 – Poor originality. The plan is very predictable and is given in basic terms with no elaboration. The plan only uses bare ideas and is commonplace and ordinary.

Example: I think that it was a great idea to hold a fashion show at the store for the anniversary of Charanmousse's opening day. This will really draw in new & old customers. We should advirste this fashion show on the radio & also on social media. We want to advirtese on social media so we can inform the younger generation, so we can have a variety of customers. Also I thought it was a good idea to sell Charanmousse products on campus during visitation week. If we provide food & drinks outside the store we will draw in men customers. For this weekend instead of creating a school spirit shirt we should have 20% off all items. A sale always attracts customers.

2 – Poor to average originality.

3 – Average originality. The plan contains something that makes it different from the typical plan. The approach is original and contains some descriptive information. Description and elaboration are present but not entirely complete.

Example: Based on the 10 scenarios introduced to market Charanmousse's products, I would take certain bits from most of them to compile a marketing plan to enter the Southern market. I believe considering competitors' products would be a smart idea. You want to be different and unique, so it wouldn't be wise to directly copy them, but maybe use their ideas to spark ways to make your product stand out more. I would also have a contest for teams to design products. After a team has revised these and picked the top designs, I would take my favorites and create them. Advertising on tv and the radio is important to draw in the older crowd, and new social media advertising is crucial to get those young adults to be in the know about Charanmousse. A fancy event with a fashion show is worth while because it will make customers feel VIP and invested in the company. Partnering with charities is one of the top marketing campaigns that would produce huge results because that is a popular thing right now. The band shirt doesn't stick out to me as being something that would be a huge hit and increase sales. Since we are trying to appeal to a crowd with expensive taste, having a celebrity model the product would be huge.

4 – Average to excellent originality.

5 – Excellent originality. The plan is exceptionally unique. The participant includes characteristics or details that make the plan unique to him/her. The plan clearly reflects an unexpected understanding approach to the problem and goes beyond the norm and presents new ideas that are highly descriptive.

Example: The biggest error I encountered when looking over the marketing plans was the cost of pushing a new product too far. When creating a new product, it is important to gather recommendations from shoppers of your company. However, these are just a select few, it doesn't guarantee that everyone will buy the product. Taking their ideas into consideration but still being cautious that the product has a chance of not going over well. I would encourage being safe on the amount of new products you order when releasing an item for the first time. Charanmousse is entering a whole new market, therefore making it smarter to just throw new ideas out here and there. If the product goes well, then order mass amounts. This will save the company when going into a new, unfamiliar market to not go into debt because amounts of unpopular products. Play the game cautiously to see how the south market reacts.

Figure 4. Example benchmark rating scale

Three doctoral students familiar with the marketing literature were asked to evaluate the participant's marketing plans using these rating scales. Prior to making these ratings, judges were asked to participate in a 5-hour training program. In this training program, judges were familiarized with the nature of the experimental task and the operational definitions of quality,

originality, and elegance to be used in appraising task performance. After presenting this material, judges applied these rating scales in appraising a set of marketing plans. Judges then met to discuss differences in product evaluations and clarify procedures for applying these rating scales in evaluating the quality, originality, and elegance of marketing plans.

Following training, adequate interrater agreement coefficients obtained were .82, .83, and .77 for evaluations of product quality, originality, and elegance. Moreover, the correlations between these appraisals of quality, originality, and elegance and the various control measures provided more evidence for the validity of these ratings. Thus, production of quality solutions was found to be positively related to divergent thinking (r = .18), conscientiousness (r = .15), and need for cognition (r = .12). Production of original solutions was found to be positively related to divergent thinking (r = .13), conscientiousness (r = .19), and need for cognition (r = .18). Production of elegant solutions was found to be positively related to divergent thinking (r = .08), conscientiousness (r = .21) and need for cognition (r = .14).

In addition to appraising quality, originality, and elegance, a second panel of three judges, all doctoral students familiar with the literature on human error, were asked to appraise attributes of the written material provided by participants with respect to errors. Specifically, judges were asked to count the number of errors identified and count the number of errors correctly identified. They were also asked to count the number of errors identified and correctly identified that participants deliberated on and remediated. Average appraisals across judges were used to specify final counts. And, as might be expected, those counts displayed substantial inter-judge agreement for counting the number of errors identified (ICC = .92).

Analyses

In the first set of analyses these count measures were correlated with each other and the quality, originality, and elegance of the marketing plans provided by participants. In the next set of analyses, a series of analysis of covariance tests was conducted to examine the effects of error deliberation and remediation on the quality, originality, and elegance of creative problem solutions. Finally, participants in the error identification conditions were compared to participants in the no error identification condition in a one-way analysis of covariance test assuming unequal cell size. It is of note in all analyses of covariance, a covariate was retained only if it was significant at the .10 level.

Results

Descriptives

Table one presents the results obtained in the correlational analysis. As may be seen, the total number and number of errors correctly identified (r = .89), deliberated on (r = .87), and remediated (r = .80) were strongly, positively, related. Given the apriori interdependence among these measures of error identification, deliberation, and remediation, this finding is not at all surprising. A somewhat more interesting pattern of findings emerged in considering the means and standard deviation of error identification, deliberation, and remediation as well as the correlation of these variables with the quality, originality, and elegance of the marketing plans produced.

Turning first to the means and standard deviations. Across all scenarios, the average number of errors that might be correctly identified was 2.8. Participants, however, identified 1.52 errors in total and 1.55 errors correctly. Thus, while participants can identify errors, they

Table 1.
Correlations for count measures and creativity

	M	SD	1	2	3	4	5	6	7	8	9
1. Number of correct errors identified	1.55	.45	1								
2. Number of total errors identified	1.52	.52	.89**	1							
3. Number of correct errors deliberated on	1.45	.39	.89**	.69**	1						
4. Number of total errors deliberated on	1.34	.37	.87**	.88**	.87**	1					
5. Number of correct errors remediated	1.38	.37	.82**	.63**	.90**	.64**	1				
6. Number of total errors remediated	1.34	.39	.80**	.89**	.77**	.95**	.80**	1			
7. Quality	2.82	.75	.34**	.32**	.14	.18	.39**	.29*	1		
8. Originality	2.65	.81	.27**	.28**	.14	.18	.35**	.27*	.74**	1	
9. Elegance	2.69	.67	.25**	.30**	.01	.10	.27*	.31*	.78**	.74**	1

** Correlation is sig at the .01 level
* Correlation is sig at the .05 level

typically appear to identify fewer errors, and correctly identify those errors, than are actually present in a scenario. Thus when presented with events, or problem solutions, people appear to underestimate the occurrence of error. Moreover, even when errors are identified, they do not deliberate on all errors or seek to remediate those errors. The mean number of errors deliberated on, either correct or total, was 1.34. The mean number of errors remediated, both correct and total, was 1.34. Thus, people appear selective in error remediation, seeking to remediate only a limited number of errors.

These biases are noteworthy given the correlations observed of error identification, deliberation, and remediation with the production of creative marketing plans. It was found the total number of errors identified and the number of errors correctly identified was positively related to the quality ($\bar{r}$ = .33), originality ($\bar{r}$ = .28), and elegance ($\bar{r}$ = .28) of participants marketing plans. Thus, error identification, especially correct identification of errors, apparently contributes to people's creative problem-solving.

The relationships produced by the deliberation and remediation variables, however, were somewhat more complex. It was found the total number of errors remediated and the number of correct errors remediated were positively related to the production of higher quality ($\bar{r}$ = .34), more original ($\bar{r}$ = .31), and more elegant ($\bar{r}$ = .29) marketing plans. Thus to produce creative problem solutions, people must try to fix identified errors – even if those errors are not real. Thus error remediation appears to contribute to creative problem-solving.

Error deliberation, however, is apparently of less value than trying to fix the errors at hand. The correlation of the total number of errors deliberated on and the number of correct errors deliberated on was not significantly related to the quality ($\bar{r}$ = .16), originality ($\bar{r}$ = .16), and elegance ($\bar{r}$ = .06) of participants marketing plans. Apparently, dwelling on errors, perhaps

by restricting information search, is not beneficial, at least not highly beneficial, for creative problem-solving.

Error Identification

Table two presents the results obtained in the one way, unequal cell size, ANCOVA containing the conditions where error identification was called for with the condition where no error identification was called for. For quality (M = 2.82, SD = .75), divergent thinking ($F(1,133) = 3.91$, $p \leq .05$) proved to be a significant covariate positively related to the production of higher quality solutions. More centrally, a significant main effect ($F(1,133) = 7.88$, $p \leq .05$) was obtained in contrasting the error identification (M = 3.17, SD = .14) and no error identification (M = 2.73, SD = .07) conditions. For originality (M = 2.65, SD = .81), conscientiousness ($F(1,133) = 4.22$, $p \leq .05$) proved to be a significant covariate. No significant difference ($F(1,133) = 2.05$, $p \leq .08$) was obtained in contrasting the error identification condition (M = 2.85, SD = .15) with the no error identification (M = 2.61, SD = .08) condition. In the case of solution elegance (M = 2.69, SD = .67), conscientiousness ($F(1,133) = 5.17$, $p \leq .05$) proved to be a significant covariate producing positive relationships with appraisals of solutions on this attribute. A significant ($F(1,133) = 3.09$, $p \leq .04$) main effect was obtained in contrasting the error identification condition (M = 2.89, SD = .13) with the no error identification condition (M = 2.65, SD = .06). Taken as a whole, these findings suggest that error identification does, in fact, contribute to creative problem-solving – a finding in keeping with the initial observations emerging from the correlational analysis.

Table 2.
ANCOVA results for identification conditions vs. no identification conditions on quality, originality, and elegance

	Quality				Originality				Elegance			
	F	df	p	η_p^2	F	df	p	η_p^2	F	df	p	η_p^2
Significant Covariates												
Divergent thinking	3.91	1	.05*	.03	-	-	-	-	-	-	-	-
Conscientiousness	-	-	-	-	4.22	1	.04*	.03	5.17	1	.03*	.04
Effects												
Identify vs. No Identify	7.88	1	.01**	.06	2.05	1	.08	.02	3.09	1	.04*	.02

** sig. at .01 level

*sig. at .05 level

Deliberation and Remediation

Table three presents the results obtained when the effects of the deliberation and remediation manipulations on the quality, originality, and elegance of solutions was examined. Although divergent thinking proved to be a significant (F (1,130) = 2.90, p ≤ .10) covariate being positively related to the production of higher quality solutions, no significant effects of the deliberation and remediation manipulations were found for solution quality.

When the originality of solutions to this marketing problem were examined, a somewhat different pattern of relationships emerged. Conscientiousness proved to be a significant (F (1,130) = 3.96, p ≤ .05) covariate with more conscientious people producing, unsurprisingly, less original marketing plans. More centrally, a significant (F (1,130) = 5.26, p ≤ .05) main effect was obtained for the deliberation manipulation. More original marketing plans were obtained in the deliberation (*M* = 2.72, *SD* = .11) as opposed to the no deliberation (*M* = 2.63, *SD* = .09) condition. Thus instructions to deliberate on errors does seem to contribute to creative problem-solving, perhaps by extensive search resulting in the production of more original solutions.

Table 3.

ANCOVA results for deliberation and remediation on quality, originality, and elegance

	Quality				Originality				Elegance			
	F	df	p	η_p^2	F	df	p	η_p^2	F	df	p	η_p^2
Significant covariates												
Divergent Thinking	2.90	1	.09	.02	-	-	-	-	-	-	-	-
Conscientiousness	-	-	-	-	3.96	1	.05*	.03	5.09	1	.03*	.04
Main effects												
Deliberation	2.39	1	.13	.02	5.26	1	.02*	.04	4.03	1	.05*	.03
Remediation	.09	1	.77	.00	1.83	1	.18	.01	.21	1	.65	.00
Interaction												
Deliberation*Remediation	.01	1	.93	.00	.145	1	.70	.00	1.05	1	.31	.01

** sig. at .01 level

* sig. at .05 level

When the effects of deliberation and remediation on the elegance of problem solutions were examined, conscientiousness proved to be a significant ($F(1,130) = 5.09$, $p \leq .05$) covariate. In this analysis, however, conscientiousness was found to be positively related to solution elegance. More centrally, a significant ($F(1,130) = 4.03$, $p \leq .05$) main effect was again obtained for the error deliberation manipulation. For solution elegance, however, it was found performance was better in the no deliberation ($M = 2.81$, $SD = .07$) condition than in the deliberation ($M = 2.53$, $SD = .09$) condition. Thus, deliberation instructions while valuable for solution originality may act to interrupt solution elegance as people pursue new, untried, problems.

Discussion

Before turning to the broader implications of the present effort, certain limitations should be noted. To begin, the present investigation was based on a classic experimental paradigm where undergraduates served as study participants. As a result, the question arises as to whether similar effects of error management would be observed in a population with substantially more experience working in the marketing domain. Although shifts in effects as a result of expertise are possible, perhaps likely, it should be recognized that neither of our knowledge or marketing expertise measures proved to be significant covariates.

Along related lines, one might question the ability of undergraduates to identify errors in marketing scenarios. The results obtained in the present effort indicated that undergraduates tended to see fewer errors in the marketing scenarios then, in fact, were there given Korte's (2003) taxonomy of common marketing errors. By the same token, however, it was also apparent that undergraduates could identify at least some of the actual marketing errors imbedded in these scenarios. Accordingly, the sample employed in the present effort does appear to provide at least a plausible initial basis for examining the impact of error identification and error management strategies on creative problem-solving.

To examine error management strategies, deliberation on identified errors and remediation of identified errors, examination of deliberation and remediation activities necessarily occurred within a context where participants had been instructed to identify and work with identified errors. Thus, the findings obtained in the present effort should not be used to draw conclusions about deliberation and remediation on creative problem-solving in general (Lonergan, Scott, & Mumford, 2004). Instead, the results obtained in the present effort speak to the value of deliberation and remediation only with respect to errors. Additionally, it is of note

that participants were asked to deliberate within a limited time frame. Prolonged deliberation may produce different results than were found in the present effort.

Finally, it should be recognized that the present study was based on a low-fidelity marketing simulation exercise (Motowidlo, Dunnette, & Carter, 1990). Although prior work by Gibson and Mumford (2013) has provided evidence indicating this particular low-fidelity simulation, Charamousse clothes, does provide a viable simulation exercise for studying creative problem-solving, the need to maximize the realism of such simulations required manipulations occur in a fixed order where deliberation preceded remediation. Thus, the present study has nothing to say about the effects that might be observed if deliberation had followed error remediation activities (Strange & Mumford, 2005).

Even bearing these limitations in mind, we do believe the present study has some noteworthy implications for understanding the significance of error identification and error management on creative performance (Hammond, Farr, & Sherman, 2011; Keith & Frese, 2008). Traditionally, students of creativity have discounted the need for people to work with errors in incidents of creative problem-solving – assuming inadequate ideas arising from errors would simply be dropped in the evaluation process. In contrast the work of Lonergan, Scott, and Mumford (2004) indicated that people must actively seek to work with, and correct, deficiencies in ideas as they evaluate and plan the implementation of creative problem solutions. This observation, in turn, suggests people must also work with errors in creative problem-solving. And, the results obtained in the present effort suggest that error identification and error management strategies may play a noteworthy role in people's creative problem-solving.

Our first hypothesis held identification of actual errors in potential problem solutions would be positively related to the production of solutions of higher quality, originality, and

elegance. In keeping with this hypothesis it was found that identification of correct errors was positively related, moderately positively related, to production of creative problem solutions of greater quality, originality, and elegance. Moreover, instructions to search for such errors was also found to result in the production of higher quality, more original, and more elegance solutions. Of course, error identification, at least identification of correct, or real, errors allows people to eliminate non-viable solution paths, ultimately, resulting in creative problem solutions of greater quality, originality, and elegance.

In this regard, however, our second hypothesis should be borne in mind. More specifically, we hypothesized that identification of more errors, regardless of whether such errors were or were not correct, would also contribute to the production of higher quality, more original, and more elegant problem solutions. And, in fact, the results obtained in the present study also confirmed this hypothesis. Error identification, regardless of whether it is correct or not, however, results in greater depth of processing (Hoffman & Frese, 2011). And, given the value of processing depth in solving novel, complex, ill-defined problems, identification of errors, multiple errors, both correct and incorrect, appears to contribute to creative problem-solving. Thus, error identification may well serve as both a stimulus for creative problem-solving as well as a vehicle for closing off non-viable paths for producing creative problem solutions.

Of course, identification of errors, and the closing off of non-viable solution paths, implies that people must attempt to remediate identified errors. In fact, this rather straight forward observation provided the basis for our third hypothesis. And, the present study provided some support for this hypothesis in the correlational analysis where it was shown that the total number of error remediation attempts and the number of error remediation attempts on actual, correct, errors were both moderately positively related to the production of creative problem

solutions of greater quality, originality, and elegance. Note not just quality and elegance but also originality as people seek ways to work around potential errors.

By the same token, the instructional manipulation intended to encourage people to remediate identified errors evidenced no significant effects. One explanation for this pattern of effects is people, virtually automatically, seek to remediate the effects of identified errors at least to some extent. As a result, instructions encouraging error remediation prove of little value because people will often attempt to do something about identified errors.

The desire to fix identified errors, however, does not necessarily imply people have really thought through the error at hand. As noted in our fifth hypothesis, thinking through errors may not prove totally beneficial in creative problem-solving efforts. As people deliberate on errors and seek ways to address these errors, problem-solving becomes more convoluted. And, these convolutions may reduce the elegance of the solution which ultimately emerges. These observations led to our fifth hypothesis. And, in fact, this hypothesis found support in our observations. Instructions encouraging deliberation on errors resulted in the production of less elegant creative problem solutions.

By the same token, our fourth hypothesis held that deliberation on errors would encourage people to consider multiple, alternative, solution paths. And, as a result, deliberation on errors was expected to improve solution originality even as solution elegance suffered. In keeping with this hypothesis, it was found that encouraging people to deliberate on errors resulted in the production of more original problem solutions.

These findings are especially noteworthy for two reasons. First, they indicate that exactly how people go about working with errors in creative problem-solving may be rather complex.

Although taking the time to identify errors may generally prove beneficial, deliberating on these errors may hurt elegance even as it contributes to the production of more creative problem solutions. This contradictory patterns of effects suggests we need more, much more, research examining how people identify errors and how they attempt to work with errors in problem-solving.

Not only is research needed on how people identify and work with errors, but research on when it is best to identify, deliberate, and remediate errors is lacking. Given the complexity of the creative thinking process, illustrated in the model proposed by Mumford et al. (1991), a better understanding of when to identify and work with errors, and at what stages of the creative thinking process, seems necessary. Indeed, further research along those lines would seem especially valuable given the available evidence pointing to both the complexity of creative thought and the likelihood of error emerging in incidents of creative problem-solving (Mumford, Medeiros, & Partlow, 2012).

Second, at a practical level, the impact of errors on creative problem-solving points to the potential value of incorporating error management training (Keith & Frese, 2005, 2008) into programs intended to develop creative potential. Indeed, prior research by Robledo, Hester, Peterson, Barrett, Day, Hougen, and Mumford (2012) also points to the potential value of error management training as a vehicle for improving people's creative problem-solving. We hope the present effort provides an impetus for further research intended to refine the principles of error management in such a way as to improve people's potential for solving creative problems.

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