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The utility of divergent and convergent thinking in the problem construction processes during
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Abstract

The process of problem construction is known to be a critical influence on creative problem-solving. The current study assessed the utility of different problem construction methods used to maximize creativity during the creative process. An experimental design was used to explore the interplay between convergent and divergent thinking processes. Participants were asked to creatively solve an ill-defined problem under four conditions that varied in their combinations of instruction to engage in divergent and convergent thinking. Findings indicated that following divergent thinking methods with a method that facilitates convergent thinking in problem construction results in more creative solutions than using only methods associated with divergent thinking. Theoretical and practical implications of these findings are discussed.

Keywords: Creativity, Creative problem solving, Creative process, Problem finding, Problem construction

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Creativity has spurred history-altering innovations ranging from the wheel to the internet and will inevitably shape life as we know it for generations to come. While the importance of pioneering profound inventions is obvious, creativity in general problem-solving should not be understated. Creative problem-solving is a key force in the success of many organizations (Florida, 2002). To survive in a competitive and global market, organizations rely on their human capital to continually devise creative solutions for overcoming the ever-changing challenges (Baer, 2012; Shalley et al., 2004; Sharma, 1999). Researchers delve into the process of creative problem-solving and its cognitive mechanisms to better understand what methods foster creativity. This article seeks to expand research in this area. The present study provides an empirical examination of methods based on cognitive processes that seek to facilitate creative problem-solving.

Creative Processes

Amabile (1983) defined creative problem-solving as the production of a novel, useful, and socially valued outcome. These outcomes can manifest as products, services, or ideas of high quality and originality. Creative problem-solving is differentiated from general problem solving by the ill-defined nature of the problem (Brophy, 1998). Problems that require creative solutions are characterized as ambiguous, unstructured, missing information, and/or having multiple potential solutions (Dillon, 1982; Mobley et al., 1991; Mumford et al., 1991).

Many models have been constructed to detail the various cognitive process within creative problem-solving. Most models of creative problem-solving agree that creative problem-solving involves three key cognitive processes: 1) problem construction, 2) idea generation, and

3) idea evaluation and selection (e.g., Dewey, 1910; Guilford, 1967; Mumford et al., 1991; Newell & Simon, 1972; Sternberg, 1986). Problem construction entails identifying and structuring a problem. After a problem is conceptualized, ideas are generated during the next general process of idea generation. The generated ideas for solving the problem are then evaluated against criteria for the anticipated outcome. Finally, the most suitable solution to a problem is selected and implemented. A growing body of research has examined each of these processes; however, not all key processes have been studied to an equal degree (Reiter-Palmon, 2018). Despite being the starting point for the creative problem-solving endeavor, problem construction has not been heavily researched (Abdulla et al., 2020; Reiter-Palmon, 2018). Because subsequent creative cognitive processes are contingent on how a problem is conceptualized, a narrow, conventional, or poor understanding of a problem limits the potential creativity of proposed creative solutions. The current study focused on the problem construction process to understand the mechanisms by which problem construction influences creative output.

Problem Construction

Ill-defined problems often entail multiple, even conflicting, goals (Schraw et al., 1995). There are multiple possible approaches to solve ill-defined problems. Before ideas can be generated, then evaluated, and selected for implementation, a process is needed to conceptualize and structure the ill-defined problem. During the problem construction process, an individual identifies, assesses, and structures a problem (Reiter-Palmon & Robinson, 2009). This stage acts as a foundation for subsequent cognitive processes. Constructing a new or unique approach to solving a problem makes the generation of creative ideas for solving the problem possible. Effective problem construction has been found to be positively associated with the creativity of

creative problem-solving efforts (Abdulla et al., 2020; Arreola & Reiter-Palmon, 2016; Reiter-Palmon et al., 1997).

Early research on constructive processes began with Csikszentmihalyi and Getzel (1971, 1976, 1988). As the study of problem construction evolved, researchers discovered that problem construction instructions could be intentionally used to facilitate creative ideation. Baer (1988) first demonstrated that providing instructions on different components of the creative problem-solving process, including problem construction, facilitated creative performance. Baer's instructions encouraged the use of the problem construction process to develop a balance of ideas that were both imaginative and workable. In a similar vein, Redmond and colleagues (1993) found that participants who were asked to restate a hypothetical problem in as many ways as possible produced solutions that were more original and of higher quality than those not given such an instruction. A follow-up study by Reiter-Palmon et al. (1997) replicated these findings using a variety of everyday, real-world problems. The authors also found that actively engaging in problem construction was associated with more original and higher quality solutions.

Instruction. Mumford and colleagues (1994) describe mental representation activation as a component of problem construction. Mental representation activation occurs when cues from the problem are mentally processed and the problem is represented in cognition. Multiple problem representations arise from the diversity of cues that are attended to (Holyoak, 1984; Mumford et al., 1994, 1996; Reiter-Palmon et al., 1997). Problem representations are schemas associated with problem-solving efforts and are stored in long-term memory (Holyoak, 1984). Specifically, problem representations contain information regarding the problem-solving effort, including the goal, any constraints or restrictions, information used during the problem-solving effort, and the process and procedure used to solve the problem (Holyoak, 1984). Holding

multiple representations may lead to the examination of a problem under many unique perspectives, leading to more creative solutions (Mumford et al., 1996; Redmond et al., 1993; Reiter-Palmon et al., 1997). Past research has focused on instructing people to generate as many restatements of the problem as they could, focusing on fluency of problem construction (Baer, 1988; Redmond et al., 1993; Reiter-Palmon et al., 1997). A major limitation of problem construction research via problem restatements is that restatements can be vague, vary in content, and make it difficult to understand the approach from which a person is constructing a problem. As a result, one potential alternative approach has been to focus on goals and constraints, which are important parts of the problem representation (Holyoak, 1988).

Instructing people to engage in problem construction via “focusing on the goals and constraints of a problem” taps the representation activation mechanism of the problem construction process and is expected to increase the number of representations activated and considered by a problem solver (e.g., Herman, 2008; Mumford et al., 1994, 1996; Reiter-Palmon et al., 1997, 1998). Asking participants to consider the goals and/or constraints of a problem before solving it can evoke problem construction (Mumford et al., 1996; Wigert, 2011). Pondering *goals* can help people look past a reactionary approach to a problem and consider a more complex, proactive, and/or future-centered approach to creatively solving a problem (Mumford et al., 1996; Reiter-Palmon et al., 1998). Also, contrary to popular belief, considering the constraints of a problem has been positively associated with creativity. Research suggests the association between constraints and creativity occurs because individuals tend to use a creative method to work around salient obstacles (Medeiros, Partlow et al., 2014; Medeiros, Steele et al., 2017; Stokes, 2007; 2009).

Mumford and colleagues (1996) found that when participants chose and focused on high-quality constraints before solving the problem, they were more creative. When participants focused their problem construction efforts on highly original goals, they were less creative. Similarly, Herman (2008) found that participants who focused on goals and constraints generated higher quality but lower originality solutions than those who did not engage in problem construction. Wigert (2011) suggests that goal fluency is associated with solution originality, and constraint fluency is associated with solution quality. Thus, it may be important to identify both as many goals and as many constraints as possible before attempting to creatively solve a problem.

While Wigert (2011) found that generating multiple goals and constraints enhanced creativity, and other studies indicated constructing problem restatements facilitates creativity (e.g., Redmond et al., 1993; Reiter-Palmon et al., 1997), the comparative effectiveness of the two methods has not been examined. It may be the case that restating a problem in as many ways as possible during problem construction maximizes creativity because such pure, unrestricted divergent thinking may allow a person to see past rules, parameters, and mental blocks created by following conventional wisdom (Guilford, 1967; McCrae, 1987). However, the ambiguity of telling someone to “restate” a problem may also be confusing. A person may simply reword the problem without considering how it could be conceptualized differently. Further, generating many seemingly unconnected restatements may create a cognitive overload that leads to more narrow thinking (Ayers & Paas, 2009; Santanen et al., 2000). As a result, subsequent idea generation, idea evaluation, and idea selection processes could be negatively affected. As such, problem construction via generating goals and constraints inherent to a problem may be a more optimal method for facilitating creativity than problem construction via focusing on restatements.

However, as both forms are expected to facilitate problem construction and creative output, both generating multiple restatements of a problem and identifying multiple goals and constraints should produce more creative solutions than not engaging in any active process.

Hypothesis 1: Participants generating problem construction goals and constraints prior to solving the problem will be more creative than participants generating problem construction restatements.

Hypothesis 2: Participants who are provided active processing instruction (either goals and constraints or restatements) for problem construction will be more creative than participants who do not receive any such instruction.

Additional Instructions

Though we expect both instructions to restate a problem in multiple ways and instruction to identify multiple goals and constraints to facilitate creative problem-solving, other instructions may also improve creativity. Proposing an alternative set of instructions to these two requires an understanding of what restatement and goals and constraints instruction have in common. Both sets of instructions may activate divergent thinking processes via the representation activation component of problem construction.

Divergent Thinking. Divergent thinking refers to the cognitive process of producing multiple alternative solutions, answers, or responses to an open-ended problem, question, or prompt (Baer, 2011; Guilford, 1967; Runco, 2008). This process has been empirically shown to be involved in creative problem-solving (Mumford et al., 1998; Reiter-Palmon et al., 1998; Runco et al., 2001). Runco and Acar (2012) note that divergent thinking is considered to be a necessary but not sufficient cognitive process behind creative production. Divergent thinking is often attributed to ideation; however, the process may occur in any creative processes that

requires the production of multiple conceptualizations. Divergent thinking processes may occur in problem construction when individuals explore branching alternative perspectives. Within the problem construction process, the representation activation component of problem construction requires an individual to begin exploring alternative and potentially novel perspectives of a problem. Representation activation may be where researchers can look evoke or stimulate divergent thinking to understand the role of instructions that evoke divergent thinking in problem construction on creative output. Novel problem representations and subsequent creative solutions arise out of identifying diverse and complex features (Mumford et al., 1994). This identification requires divergent thinking (Hocevar, 1980; Runco, 1991). When many representations are produced a divergent thinking process can be said to have occurred. Attention to a large number of associated representations in turn opens the door to new ways of looking at a problem, and consequently, creative approaches to solving it. As such, it seems that novel problem representations, and subsequent creative solution alternatives, could not exist without divergent thinking during problem construction.

Similar to how previous studies make use of tasks that instruct people to generate multiple responses to evoke and measure divergent thinking in a general form (e.g., Mumford et al., 1998; Plucker, 1999; Runco, 1986; Runco et al, 2001), instructing people to “restate a problem in as many different ways as possible” may evoke divergent thinking as it occurs in problem construction by tapping the representation activation mechanism of the problem construction process. Redmond et al. (1993) and Reiter-Palmon et al. (1997) evoked divergent thinking during problem construction by instructing participants to restate a problem many times before solving it. These instructions were designed to simulate the representation activation component of problem construction. In these experiments, participants tended to be more

creative when such instructions were provided. Wigert (2011) linked a more specific component of representation activation, the production of goals and constraints, to creative outcomes. Specifically, Wigert found that the number of goals and constraints produced during problem construction was positively related to the creativity of participants' solutions. Similar to how producing multiple representations implies the occurrence of divergent thinking, producing multiple goals and constraints should also imply the occurrence of divergent thinking. As such, instructions that tap into the goals and constraints component of representation activation might evoke divergent thinking and improve creative output. It is important to note that these instructions to generate multiple restatements or multiple goals and constraints focus on one aspect of divergent thinking, that of fluency.

Convergent Thinking. The mechanisms of problem constructions are not limited to only divergent thinking processes. The counterpart to divergent thinking is convergent thinking. Convergent thinking refers to a top-down approach to synthesizing information in order to construct the single best possible answer to a problem (Cropley, 1967). It typically entails accumulating information, applying a logical search of information, recognizing familiar associations between concepts, applying one's knowledge, and leveraging conventional decision strategies (Cropley, 2006). In the creative problem-solving process, convergent thinking is employed when divergent thinking results in multiple ideas (Runco & Chand, 1995). A convergent thinking process is needed to evaluate and select ideas for implementation (Blair & Mumford, 2007)

Both divergent and convergent thinking processes are thought to be involved in problem construction (Reiter-Palmon & Murugavel, 2020). A diverse network of representations is useless if they cannot be evaluated, connected, and combined to form a coherent problem

construction(s). In problem construction, a convergent process is used to filter and combine representations. Previous research has indicated that spending time combining and reorganizing extant concepts prior to taking action was associated with more creative production (Finke et al., 1992; Kuhn, 1970; Rothenberg, 1986). Mumford and colleagues (1997) find that effective combination and reorganization of categories—an aspect of convergent thinking—was positively associated with participants' creativity.

Basadur (1995) proposed that problem construction begins with the divergent act of identifying what aspects of a problem can be used to conceptualize it, and problem construction concludes with convergent thinking that helps an individual choose exactly which aspects of a problem will be used in its final conceptualization. Problem construction inherently requires one to identify divergent problem elements before converging on a single problem representation. Mumford et al. (1994) described a convergent thinking process of screening problem representations. Without such a process, the numerous goals, constraints, and parameters surrounding an ill-defined problem may overwhelm the creative problem-solving effort. Further, similar to how instructions may be used to stimulate a divergent thinking in problem construction, instructions to evaluate and select among many conceptualizations may stimulate convergent thinking. When multiple problem constructions are considered then reduced to one to support ideation, convergent thinking can be implied to have occurred. Convergent thinking during problem construction is a mechanism for addressing whether problem representations should be retained and how they should be combined. The final problem representation resulting from the problem construction process will likely only contain information that was deemed important after a screening process. Thus, the solution generation process will be limited to definitive judgments made after a convergent thinking process that occurred during problem

construction. Consequently, when people engage in convergent thinking after actively applying divergent thinking processes in problem construction, they are likely to produce more creative solutions. However, past research on problem construction has focused almost exclusively on the divergent process of problem construction, through instructions to generate multiple restatements. The role of convergent thinking within this process, while identified theoretically, has not been experimentally evaluated.

Hypothesis 3: Individuals who are provided instructions that engage both divergent thinking and convergent thinking processes during problem construction will generate more creative solutions than individuals who only engage in divergent thinking during problem construction.

Method

Participants

We recruited 350 participants via Amazon Mechanical Turk (Mturk). Participants were asked to complete an online study regarding problem-solving and creativity. Participation was limited to those from the United States. Additionally, to reduce the frequency of poor quality responses, participation was further limited to people who had completed ten previous MTurk surveys without noted complaints. Participants were paid \$2 for the completion of the study, which at the time of data collection was considered above the pay rate for surveys such as this. Responses from 310 (120 males, 189 females, and one unspecified) participants were retained after removing those that did not pass embedded quality or manipulation check control questions. The average participant age was 34.45 years ($SD = 11.97$). Within the sample, 78.1% of the participants were European American/White, 7.1% were African American/Black, 5.8% were Hispanic or Latino, 3.5% were Asian American/Pacific Islander, 1.0% were Native American, and 4.2% indicated “Other” as the race with which they most identified. The 310 participants

were asked for their highest level of education completed, and 36.8% graduated from college, 32.6% were in or attended some college, 15.2% graduated from high school or completed a GED, 1.3% completed a Ph.D., and 1.3% attended but did not graduate from high school.

Procedure and Design

Participants were given an ill-defined problem appropriate for the knowledge and life experience of most college students that had been used in previous creative problem-solving research (Reiter-Palmon & Arreola, 2015). The problem presented a dilemma touching on subjects related to work, money, ethics, and social issues. In the problem, a college student is working a steady job at a pizzeria. The student notices that her coworker, who is also her friend and rent-paying roommate, has been stealing pizzas. The student must balance the interests of herself, her boss, and her coworker to resolve the dilemma. Participants are asked to provide a solution for the college student.

After reading the problem, participants were randomly assigned to one of five sets of instructions that manipulated engagement in divergent and convergent thinking during problem construction. A 2 (generate goals and constraints vs. generate problem restatements) X 2 (instructions to identify vs. no instructions to identify) between-subjects experimental design was used in this study. A fifth condition (no problem construction before solving the problem) acting as a control condition was also included.

Before engaging in problem construction, participants were told that they would be providing a creative solution to the problem. “Creative” was defined to participants as a solution that is both original and of high quality. To examine the conditions that best facilitated the divergent thinking aspect of problem construction, instructions for actively engaging in the problem construction process were manipulated. Participants were either told to generate

multiple goals and constraints for the problem or told to generate multiple restatements of the problem. For the manipulation of convergent thinking, participants were given (or not given) instructions related to evaluation and selection. Specifically, participants were instructed to provide ratings of the importance of their goals and constraints to resolving the problem at hand (or restatements, depending on the problem construction instruction manipulation that they received) on a 5-point Likert-type scale (1 = very unimportant; 5 = very important). Then, participants were asked to select all goals and constraints (or restatements) that they intend to address when solving the problem. This method is aligned with work on the idea evaluation process of creativity (e.g., Benedek et al., 2016; Silvia, 2008; Reiter-Palmon et al., 2018; Runco & Basadur, 1993; Runco & Vega, 1990) whereby researcher use Likert-type scale ratings to examine forms of convergent thinking (i.e., evaluation and selection) in participants. In the present study, a similar process was used. However, instead of asking participants to rate and select ideas, participants were asked to evaluate and select either their goals and constraints or representations. After these instructions, participants were asked to provide an original and high-quality creative solution to the problem. Participants were given a series of surveys and tasks measuring covariate variables after providing a solution to the presented problem. A demographics questionnaire was presented at the end of the study.

Solution Creativity

Following a method used in previous research (e.g., Mumford et al., 1996; Reiter-Palmon et al., 1998), creativity was assessed by asking three independent judges to rate the of participants' solutions to the presented problem. Creativity was operationalized using the common two-criteria definition, whereby creativity is considered the product of originality and quality (Sternberg & Lubart, 1999). These judges were undergraduate and graduate students

who had previous experience and training in rating solutions on dimensions of creativity. Raters assessed the originality and quality of each solution using two 5-point Likert-type scale with anchors ranging from 1 (*very unoriginal/ very low quality*) to 5 (*very original/ very high quality*). Raters were trained to apply interval rankings to ideas based on three components of originality: novelty, imagination, and structure. Definitions for these components and definitions for scale anchors were provided (see Appendix A for more detail). Similarly, raters were trained to identify completeness and effectiveness for the quality dimension of an idea (see Appendix B for more detail). Scale anchor definitions for quality were also provided. Raters were also trained to rate ideas relative to the full set of ideas from all participants. That is, a score of five should be given to most creative ideas produced for this study. Metrics of inter-rater agreement and reliability were used to determine the agreement among raters to denote the validity and reliability of construct measurement. Both originality ratings (r_{wg} of .88, and an ICC(2) of .92) and quality ratings (r_{wg} of .84, and an ICC(2) of .89) were found to be at high levels indicating sufficient agreement among raters (Shrout & Fleiss, 1979; LeBreton & Senter, 2008) and a valid indication of solution creativity (Amabile, 1983; Baer et al., 2004; Mumford et al., 1997). As such, the ratings from judges were aggregated using an arithmetic mean to produce a single originality score and a single quality score for each solution. Then, each participant's originality and quality scores were multiplied together to create a composite creativity score for each participant. Multiplication is favored over addition when composing creativity scores as low scores on one component impacts the composite score value more. That is, solutions that are high in quality but low in originality, or vice versa, would result in lower scores than solutions that are moderate in quality and originality (Simonton, 2012; Simonton & Damian, 2013). This approach resonates with the definition that creative products must be both novel and useful

(Amabile, 1983). Additionally, as expected, the average originality and average quality of solutions were positively correlated, highlighting the multi-dimensional nature of the multiplicative overall creativity score used to assess each solution. That is, solution originality and quality are related, but not redundant, aspects of creativity.

Covariates

The problem construction task in this study is focused on the generation of multiple ways to think about the problem; therefore, divergent thinking fluency was selected as a covariate to control for fluency. Further, previous research has suggested that general intelligence, convergent thinking ability, self-efficacy, and task interests are related to creative problem-solving. As such, these variables were included as covariates to better attribute observed condition differences to study manipulations.

General intelligence. General intelligence, a well-known correlate of creativity, was controlled for in the current study to better isolate the effects of the studied problem-solving processes on creativity (Barron & Harrington, 1981). As such, the Raven's Advanced Progressive Matrices (APM) assessment was given to all participants (Raven et al., 1998). The APM is a non-verbal test of reasoning ability that requires participants to identify the missing element that best completes a pattern.

Fluency. Since the divergent thinking instruction manipulations relied on the fluency aspect of divergent thinking within problem construction, differences in participant ability to be fluent on generation tasks may obscure variability between conditions designed to isolate and expose the functions of problem construction. We used fluency as a control variable to better attribute observed conditional difference to differences in problem construction operation. Two tasks from Guilford's (1967) Alternative Uses Task were used. In the first task, participants were

asked to “identify as many uses as possible for a **brick**”. The second task asked to “identify as many uses as possible for a **paperclip**”. The total number of responses generated provided a score of participant fluency.

Convergent thinking ability was assessed using a shortened version of Mednick and Mednick’s (1976) Remote Associates Test (RAT). This version of the RAT included 17 items of varying difficulty. Each item shows the participant three cue words and instructs the participant to generate a fourth word that links the three cue words

Problem Self-efficacy. Participants’ self-perceived ability to solve the presented problem may influence their creativity. As such, self-efficacy—one’s perceived ability to successfully complete a specific task—was assessed to determine whether it co-varied with creativity in the current study. Sherer et al.’s (1982) three-item self-efficacy scale was given to participants (e.g., “I am very confident I could solve the problem”). The responses to the items were collected using a five-point, Likert-type scale (1 = *strongly disagree* to 5 = *strongly agree*; Cronbach’s $\alpha = .86$).

Task interest. Furthermore, participants’ creativity may depend on how much interest they have in effortfully trying to solve the presented problem. As such, task interest was assessed using Elliot and Harackiewicz’s (1994) measure. Participants responded to five survey items using a five-point Likert-type scale (1 = *strongly disagree* to 5 = *strongly agree*). E.g., “The problem-solving task was very interesting” (Cronbach’s $\alpha = .46$).

Results

See Table 1 for correlations and descriptive statistics for all variables of interest. The influence of divergent and convergent problem construction instruction on creative problem solving was tested using analysis of covariance (ANCOVA) and standard regression analysis

procedures. Hypotheses 1 and 3 were tested via a 2 (goals/constraints instructions vs. restatements instructions) X 2 (instructions to identify vs. no instructions to identify) between-subjects ANCOVA. Covariates in the model included: task interest, self-efficacy, general intelligence, convergent thinking ability, and divergent thinking ability.

Hypothesis 1 predicted that participants who generated problem construction goals and constraints prior to solving the problem would be more creative than participants who generated problem construction restatements. A test of the main effect for the type of divergent thinking instruction provided (goals/constraints vs. restatements) indicated that Hypothesis 1 was not supported. Findings from testing this hypothesis indicated that the divergent thinking methods employed across these conditions could be treated as equivalent. For subsequent analysis, the restatement and goals and constraints instruction conditions were combined before comparing another condition. Table 2 details the results of this ANCOVA. Figure 1 shows estimated marginal means of solution creativity scores per each condition.

Hypothesis 2 predicted that participants who were provided active processing instruction for problem construction would be more creative than participants who do not receive any such instruction. A similar ANCOVA was used to test this hypothesis. In this analysis, the divergent thinking instruction conditions (i.e., restatements and goals and constraints combined together) were compared to the control condition, which did not provide any instruction to participants. Table 3 details the results of the ANCOVA. As with the first ANCOVA, task interest, self-efficacy, general intelligence, convergent thinking ability, and divergent thinking ability were included in the model as covariates. The main effect for instruction for active engagement in divergent thinking in problem construction (vs. no such instructions) was not found to be

statistically significant; thus, divergent thinking instructions alone did not influence creativity in the current study. Hypothesis 2 was not supported.

Hypothesis 3 predicted that individuals who were given instructions to engage in divergent thinking and convergent thinking during problem construction would be more creative than individuals who were given instructions to engage them in divergent thinking during problem construction. Results indicated support for this hypothesis. Participants instructed to evaluate and select (i.e., convergent thinking) during problem construction generated in more creative solutions than those who were given only divergent thinking instructions (see Table 2 for more details).

Discussion

The current study examined the utility of two previously studied problem construction methods—the identification of problem restatements and the generation of goals and constraints before solving a problem. Additionally, while theory and empirical evidence have emphasized that divergent thinking enables one to be creative, few studies have explored how convergent thinking influences problem construction and creativity. This study addressed this research gap by also exploring the utility of providing convergent thinking instruction during problem construction to improve creative output.

It was expected that focusing attention on the goals and constraints of the problem would enhance creativity by means of inspiring one to look at a problem from more comprehensive and unique perspectives, a process that is not intrinsic to forming restatements. Contrarily, this study found that the creativity of individuals' solutions did not differ in their creativity as a function of whether they generated goals and constraints or restatements. Although a null finding, this result lends support to the equivalence of the two examined methods of divergent thinking in their

ultimate effect on creative problem-solving. Both approaches to evoking divergent thinking during problem construction entail redefining the problem at hand in one's own words. It may be the case that participants generated restatements with the goals and constraints of the problem in mind. Alternatively, participants may have simply tried to list goals and constraints in a manner that restated the problem. Smith et al. (2013) note that convergent thinking processes such as addressing constraints may first require memory search processes resembling divergent thinking. This finding further supports that instruction related to constraints may invoke divergent thinking. The lack of difference between the two approaches also suggests that how one initiates divergent thinking may be less important to the problem construction process than the underlying cognitive processes and decision strategies that occur during problem construction.

Although much of the creativity literature purports a consistent relationship between problem construction and creativity (e.g., Arreola & Reiter-Palmon, 2016; Harms et al., 2020; Mumford et al., 1996, 1997; Redmond et al., 1993; Reiter-Palmon et al., 1997, 1998), instructing an active divergent thinking problem construction process did not facilitate creativity in this sample. However, people who simply solved the problem were just as creative as individuals who were instructed to engage in divergent thinking processes during problem construction. The absence of an effect for divergent thinking may have resulted from a varied application of problem constructions among participants. Wigert (2011) found that simply instructing participants to generate goals and constraints did not facilitate creativity. However, when participants generated goals and constraints that were more original, of higher quality, and of greater fluency, they tended to be more creative. Thus, active problem construction may only be useful when participants' application of instruction leads to truly redefining the problem in novel and appropriate ways. In fact, Arreola and Reiter-Palmon (2016) have found that the quality and

originality of problem restatements were directly related to the quality and originality of the solutions generated. As such, future work involving problem construction should evaluate the actual engagement in the process through measurement of quality and originality of the restatements and not only rely on instructions. Additional boundary conditions that explain when active engagement in problem construction processes provides more utility than passive engagement need to be explored.

Although divergent thinking instructions focusing on fluency did not seem to be related to improved creativity, a relationship between convergent thinking instruction and solution creativity was found. Those who were instructed to evaluate and select their goals and constraints or restatements produced more creative solutions than those who did not receive such instruction. Relative to divergent thinking, convergent thinking was especially key to leveraging the problem construction process to explore and refine raw information into a more original, higher quality solution in this study. The process of carefully considering the salience of each piece of divergently generated information before deciding what concepts should be incorporated into a solution to the problem was found to aid the creative problem-solving process. Convergent thinking appears to have helped individuals organize, evaluate, and select information that expanded their understanding of the problem, and subsequently, the creativity of their solutions.

The positive association between convergent problem construction processes and creativity may lend insights into previous research that found solution revision to enhance creative problem-solving (Mumford, 2003). Revisions to a solution occur after initial idea generation, let alone an initial problem construction process. The revision process involves revisiting the problem's construction itself. To revise a solution, one must consider how a solution can better address a problem before the solution can be reconfigured. Therefore, one

must engage in problem construction another time before generating a new or modified solution. For that reason, the current study and Mumford (2003) likely tap into the same convergent aspect of the problem construction process. It seems that in both studies, the original understanding and construction of the problem was less important than how salient aspects of the problem were evaluated and addressed. Theoretical models developed by Basadur (1995) and Brophy (1998, 2001) tell a similar story of how divergent and convergent thinking are believed to iteratively identify and meld information, but for the first time, the current study has identified how actionable decision-making processes, activated during problem construction, evoke creativity. The current study shines a light on the traditional overemphasis of finding new ways to initiate and study divergent thinking. Creative cognition seems to be more heavily influenced by what individuals do with the information that they divergently generate. Facilitating problem construction need not be limited to solely instructions that activate divergent thinking processes.

Future research is needed to unveil the mechanisms by which convergent thinking can be optimized and aligned within the problem construction process. Various methods of organizing and evaluating information during problem construction may yield different types of output. Not only does convergent thinking eliminate distracting information and improve focus on issues that are most salient to a problem, but it likely is used to establish a firm ground upon which other creative problem-solving processes occur (i.e., idea generation and idea evaluation).

Moreover, general research on convergent and divergent thinking during creative cognition has suggested that both divergent and convergent thinking contributes to creativity, but divergent thinking is considered the primary factor. Most of these studies were solely focused on the idea generation stage of creative cognition. The current study further informs this body of knowledge by indicating that divergent and convergent thinking abilities can make nearly equal

unique contributions to enhancing creative problem-solving. Furthermore, the current study suggests divergent cognitive processes may not consistently facilitate creative thinking if they are not followed by adequate convergent thinking processes.

Additional research is needed to determine whether findings from the current study also apply to idea generation and evaluation processes. As was found for problem construction, a balance between divergent and convergent thinking processes may be key to optimizing creative performance. Research on other creative processes should look to examine both divergent and convergent cognition together. Understanding these processes can help identify how problem construction, idea generation, and idea evaluation methods can most effectively be linked to complement one another.

Limitations

The method used to survey a sample of participants may affect the generalizability of this study's conclusions. A major benefit of using MTurk was that the average age and geographic distribution of participants were much greater than that of a student sample because the study sample was recruited from the United States' general population. Still, according to Keith et al. (2017), caution should be used when using the MTurk platform as means for conducting survey research. There are two drawbacks to consider when using MTurk samples. One drawback is that MTurk workers may have commonalities that make them available and willing to complete online work for small amounts of pay. As such, Mturk samples do not perfectly resemble the totality of the North American workforce. Specific characteristics in this pool of participants may affect the generalizability of the collected data (Keith et al., 2017). Another drawback of MTurk samples is data quality. However, Keith et al. identified survey and data collection quality control options as mechanisms to ensure that data collected from MTurk samples would be of

high quality. The current study used such quality control screening questions to identify and exclude poor quality responses from analyses.

The focus of the divergent thinking manipulation was that of fluency, one that has been used effectively in the past to induce problem construction (i.e., Arreola & Reiter-Palmon, 2018; Redmond et al., 1993; Reiter-Palmon et al., 1997). Indeed, instructions for divergent thinking have an important influence on the outcome of the generation of ideas (Reiter-Palmon et al., 2019). Instructions that focus on fluency (generate as many as you can) result in increased fluency, whereas instructions that focus on creativity result in more original and creative ideas. It is possible that one reason for the lack of effect found for the divergent thinking instructions is the focus on fluency as opposed to other aspects of divergent thinking such as originality. Future research should evaluate the role of such instructions beyond traditional divergent thinking tests such as the alternative uses and evaluate the effect of differing instructions on problem construction tasks.

Additionally, although results revealed a clear positive main effect of convergent thinking on creativity, some caution should be given when considering the implications of this finding. The convergent thinking conditions that facilitated creativity included an extensive second phase of problem construction; whereas, the other three conditions included no more than a short single stage of problem construction. As such, it is possible that the amount of time spent constructing problems or the complexity of the problem construction process had a greater effect on creativity than the actual act of convergent thinking. This alternative hypothesis could be tested by comparing the relative effectiveness of the convergent thinking manipulations in relation to longer, more complex divergent thinking processes.

Furthermore, the characteristics of the ill-defined problem used in this study may have also affected the results. Ill-defined problems can vary on many characteristics. A study by Runco and colleagues (2005) found that participants developed more appropriate responses to realistic than unrealistic divergent thinking tasks. Conversely, participants generated more original and more flexible solutions to unrealistic tasks. Problem domain can also affect creative problem-solving and problem construction (Mumford et al., 1994; Rostan, 1994). The problem solver's experience and expertise in a domain can affect how they construct problems (Arreola & Reiter-Palmon, 2013; Mumford, Supinski, et al., 1997). Drawing conclusions from only one ill-defined problem with one set of characters and that falls to one domain limits the external validity of this study. To ensure that this study's findings generalize to other situations, the same experimental instructions should be tested on different types of problems and in different domains. Finally, this study focused on using ways to facilitate problem construction through instructions. The degree to which participants are able to understand the problem, and therefore the degree to which the problem construction manipulation evaluates problem comprehension, was not determined in this study and should be evaluated.

Conclusion

The study of problem construction is essential to understanding how people produce creative solutions. The current study sought to examine how instructions for active engagement in problem construction best facilitate creative problem-solving. This study provides initial empirical evidence suggesting that the most creative solutions do come from a sole focus on divergent thinking procedures (e.g., looking at the problem in as many different ways as possible) during problem construction. Convergent thinking critically influences how one

cognitively processes information and decides upon which aspects of a problem should be combined, ignored, further explored, and applied to the solution.

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Table 1. *Intercorrelations and descriptive statistics between study variables*

	<i>M</i>	<i>SD</i>	1	2	3	4	5	6	7
1. Solution Creativity	9.92	5.08	-						
2. Solution Originality	3.03	0.99	.60*	-					
3. Solution Quality	3.10	0.97	.84*	.91*	-				
4. Task Interest	2.99	0.34	.07	.07	.06	-			
5. Self-Efficacy	3.64	0.88	.04	.15*	.09	.40*	-		
6. General Intelligence	5.61	2.59	.21*	.27*	.28*	-.04	-.22*	-	
7. Convergent Thinking Ability	12.61	4.18	.26*	.22*	.25*	-.03	-.12*	.25*	-
8. Divergent Thinking Ability	13.49	8.76	.23*	.29*	.29*	.01	-.02	.29*	.21*

Note. $N = 310$. Correlations are two-tailed. *M* and *SD* refer to mean and standard deviation, respectively.

* $p < .05$.

Table 2. *Hypothesis 1 ANCOVA Results for the Influence of Divergent and Convergent Problem Constructions Processes on Creativity*

Independent variable	Type III SS	df	MS	F	η^2
Corrected Model	1373.01	8	171.63	7.95*	.22
Intercept	2.00	1	2.00	0.09*	.00
General Intelligence	434.07	1	434.07	19.14*	.09
Convergent Thinking Ability	202.32	1	175.47	8.92*	.04
Fluency	140.55	1	104.37	4.83*	.02
Self-Efficacy	204.48	1	228.15	9.02*	.05
Task Interest	1.10	1	1.10	0.05	.00
DT instruction (Goals vs. Restatements)	0.07	1	0.07	0.03	.00
CT instruction (vs. no CT instruction)	72.17	1	72.17	3.34*	.02
DT x CT instruction Interaction	0.38	1	0.38	0.02	.00
Error	4772.55	225	21.60		
Total	31199.47	234			
Corrected Total	6145.56	233			

Note. * $p < .05$. CT = Convergent Thinking. DT = Divergent Thinking.

Table 3. *Hypothesis 2 ANCOVA Results for the Influence of Engaging in Problem Construction Processes*

Independent variable	Type III SS	df	MS	F	η^2
Corrected Model	1446.13	6	241.02	11.91*	.18*
Intercept	0.90	1	.90	0.04	.00
General Intelligence	252.80	1	252.80	11.74	.04
Convergent Thinking Ability	244.81	1	244.81	11.37	.04
Fluency	257.79	1	257.79	11.97	.03
Self-Efficacy	154.75	1	154.75	7.18	.03
Task Interest	0.56	1	0.56	0.03	.00
Problem Construction (vs. no PC)	44.62	1	44.62	0.15	.01
Error	6126.01	297	20.63		
Total	38304.69	309			
Corrected Total	7950.59	308			

Note. * $p < .05$. PC = Problem Construction.

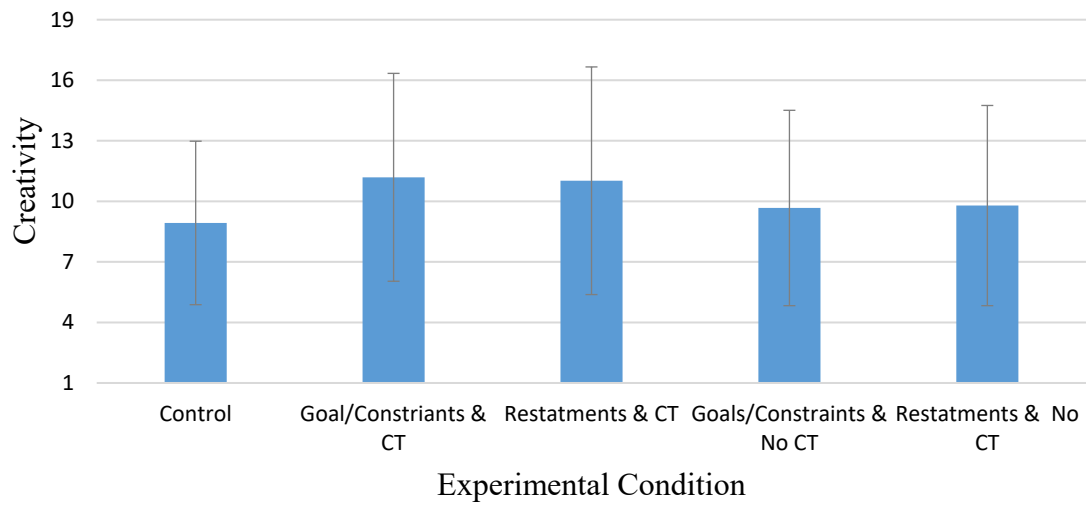


Figure 1. Mean Comparisons of Creativity by each Experimental Condition

Appendix A

Originality

Solutions should be rated on a 5 point scale based on the following criteria:

Novelty - Does the solution represent a relatively unique approach to the problem (relative to other solutions)?

Imagination - Does the solution present an imaginative or humorous approach?

Structure - Is the solution structured and limited by the problem as presented? Does the problem solver question the assumptions presented in the problem? Does the solution show thinking outside the box?

1. Very unoriginal - simple solution, minimum effort, no more than one idea.
2. Unoriginal- Simple but complete solution. One that is not novel, not imaginative, and is structured by the problem.
3. Neutral (neither unoriginal nor original) - Solution shows limited novelty or imagination, is still structured by the problem.
4. Original - Solution shows some novelty and imagination and is less structured by the problem.
5. Very original - Solution is unique and novel, imaginative, and not structured by the problem.

Appendix B

Quality

Answers to the problem should be rated on a five point scale based on the following criteria:

Completeness: Is the solution complete and address multiple issues raised by the problem?

Effectiveness: Is the solution viable, feasible, practical or appropriate?

1. Very low quality - Solution incomplete, minimum effort.
2. Low quality - Simplistic solution, no elaboration, addresses only one point/issue or is probably not feasible.
3. Average quality - Solution tries to address more than one issue/point, but does so poorly, or with minimum elaboration.
4. High quality - Solution addresses 2 or more issues in the problem and is effective in addressing one and at least reasonably effective in addressing the other.
5. Very High Quality - Solution addresses 2 or more issues and is effective in addressing all.