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Groups as Analogical Information Processors: Implications for Group Creativity

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Groups as Analogical Information Processors: Implications for Group Creativity

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Dedication

For Pam, Jackson, Addison, Ashlyn, and Grace Anne. You made many sacrifices while I was pursuing this goal, and I could not have done this without you. Thanks for believing in me.

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Groups as Analogical Information Processors: Implications for Group Creativity

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Organizations routinely rely on work groups for creative solutions to the problems they face. This is because solving difficult problems is often assumed to require the talents and knowledge of multiple people working together. However, much research has shown over the years that groups frequently experience dysfunction when trying to collaborate and generate creative solutions. Organizational researchers have theorized that analogical reasoning may play an important role in promoting collective creativity, but these claims are for the most part untested in the literature. In this dissertation, I attempt to answer two questions. First, does analogical reasoning provide some functional benefits for groups solving creative problems? Second, does analogical reasoning give rise to synergistic effects when creative groups collaborate during ideation and problem-solving? I assessed these questions using a laboratory study designed to find the effects of analogical reasoning in interacting and non-interacting groups, and to test for potential synergistic effects of analogical reasoning as a group-level strategy for generating creative problem solutions. Findings of the study suggest that analogical reasoning may provide some benefits for creative group outputs, and it may also create synergistic effects for creative groups.

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INTRODUCTION

Ever-changing markets and technologies require many organizations to act creatively. New and more useful technology, equipment, and work processes are often needed to increase productivity, which can boost profitability and help firms compete against rivals. Meanwhile, consumers consistently crave new and more useful products and services. These internal and external demands put pressure on firms to come up with new, creative ideas. As a result, organizational prosperity and long-term survival frequently depend on creative thinking that leads to innovation (Schumpeter, 1976).

Organizations often use work groups to generate new ideas, instead of relying on individuals for creative thinking (Thompson, 2013). The popular common sense about solving difficult problems, including creative problems, is based in part on two propositions. The first is a resource-based argument: Groups have an advantage over individuals because they possess more knowledge and experience as a collective than any individual can possess alone. This rationale gives groups a hypothetical advantage over individuals, when it comes to creative problem-solving. The second derives from the notion of *synergy* (Baruah & Paulus, 2009; Larson Jr, 2010), which assumes there is something special about inter-member interaction that propels group achievement beyond what is expected based on the "sum of its parts". Taken together, these propositions suggest functional benefits for groups over individuals when it comes to creative problem-solving. However, one conclusion that can be drawn from decades of scholarly research is that groups are at risk of succumbing to dysfunctional processes that prevent them from effectively taking advantage of their inputs and resources (Hackman, 1987, 1998; Steiner, 1972). If organizations are to benefit from using creative groups, then the creative group processes that involve inter-member collaboration must be functional. The widespread use of creative groups in organizations necessitates that researchers develop and test theory that accounts for these processes and their impact on group creativity.

Creative problem-solving is a challenging topic for serious study. Figuring out where new ideas come from has been called "an enormous question" (Smith & Ward, 2012) and "the most daunting question in psychology" (Markman & Wood, 2009). Existing creativity research contains varying perspectives. For example, some early creativity research emphasized personality and other individual differences in creative ability (e.g., Guilford, 1950; Mackinnon, 1965). Newell, Shaw, and Simon (1962) assumed that individual creative thinking was a special class of human problem-solving, and theoretically modeled it as a process of goal-driven symbolic information processing. More recent research has approached individual creative thinking processes by applying concepts from cognitive science (Smith & Ward, 2012; Smith, Ward, & Finke, 1995). One such area of inquiry is focused on understanding how *analogical reasoning* can stimulate creative thinking processes and produce creative outcomes (Gentner et al., 1997; Markman, Wood, Linsey, Murphy, & Laux, 2009).

Analogical reasoning involves abstract thinking during creative problem-solving, which promotes variety and novelty in potential solutions. At the same time, analogical reasoning also requires some disciplined analysis and evaluation, which helps increase the chances that solutions will effectively address the creative problem. This combination of variety and discipline of thought makes analogical reasoning potentially well-suited as a creative thinking technique (Gentner et al., 1997; Hargadon, 1999).

Some have suggested that analogical reasoning might also be beneficial for group creative processes and outcomes (Amabile, 1996; Hargadon, 1999; Hargadon & Bechky, 2006; Shalley & Perry-Smith, 2008), but theory derived from this conjecture is scant and associated empirical tests are missing in the literature. In fact, much evidence exists that ideation strategies may actually produce process losses when implemented in interacting groups (Diehl & Stroebe, 1987; Mullen, Johnson, & Salas, 1991). If analogical reasoning is to benefit group creative problem-solving, it must overcome or avoid the social and cognitive process losses that these existing ideation strategies such as brainstorming are subject to.

In this dissertation I investigate the role of analogical reasoning in creative problem-solving groups. Specifically, I examine how analogical reasoning affects group information processing and how implementing an analogical reasoning strategy produces creative group outcomes. I argue that analogical reasoning provides group-level benefits for idea search and collective evaluation, each of which is critical to group processes leading to creative problem-solving. Further, I argue that employing an analogical reasoning strategy will produce synergistic benefits for interacting groups.

This research applies to group tasks that are primarily cognitive and intellectual in nature. These tasks often require members to contribute and integrate their diverse knowledge in order to generate new solutions to organizational problems and opportunities. Member cognitive interdependence is a requirement for tasks like these, in the sense that members must usually retrieve, share, and build upon others' knowledge to achieve a high level of effectiveness. Examples of teams that often engage in these types of tasks are new product development teams, creative advertising teams, R&D teams, management consulting teams, and temporary teams composed specifically to solve emergent crises in organizations.

This research contributes to the group creativity literature by examining group creative process, a currently understudied yet important area of inquiry. Much of the existing group creativity literature treats group creative process as a "black box," studying group creative outcomes as stemming from group compositional and contextual inputs (Shalley, 2008). This dissertation also contributes to the research on analogical reasoning, the bulk of which has been conducted at the individual level of analysis. Finally, because it explicates the theoretical mechanisms involved in creative problem-solving, this dissertation may shed light on collective cognition more generally, and it may complement recent efforts to study group creativity using concepts from group cognition (Gino, Argote, Miron-Spektor, & Todorova, 2010).

This research is intended to have an impact on real organizations by helping managers establish working conditions and practices that spur group creative outcomes and increase the chances that group creativity will lead to beneficial organizational outcomes. Managers often do not have much control over the personnel available for projects, but they sometimes can control the working environment and training programs to a greater extent and "set the conditions" for optimal group outcomes (Hackman, 1987). In addition, this research may ultimately lead to recommended interventions that will foster enhanced group creativity in the workplace.

The remainder of this dissertation unfolds as follows: In Chapter 2, I review relevant literatures from organizational behavior and cognitive science that establish what is known about group creative processes, group creative outcomes, and analogical reasoning. In Chapter 3, I theorize about the nature of analogical reasoning in group contexts and why analogical reasoning might promote various aspects of group creativity. I present testable hypotheses that relate analogical reasoning to group information processing and creative problem-solving. In Chapter 4, I present the methods for testing the hypotheses. The study design is a laboratory experiment. In Chapter 5, I present the results of the data analyses. Finally, in Chapter 6, I discuss the empirical results, describe the limitations of the study, suggest how the results apply to creative groups in theory and practice, and recommend where the research ought to go from here.

Chapter 2: Literature Review

CREATIVITY: DEFINITION AND CONCEPTS

In the following section, I define creativity for the purposes of this dissertation and introduce some important concepts related to the study of group creative problem-solving.

Creativity Defined

Creativity is defined as the generation of ideas that are both *novel* and *useful* (Amabile, 1996; George, 2007). Creativity may therefore manifest as a *creative process* (the generation of ideas) that results in *creative outcomes* (i.e., products that are novel and useful). Another specification is that the creative task itself must be one for which a completely straightforward path to a solution does not exist, i.e., the task must be heuristic and not algorithmic (Amabile, 1996). Creativity and innovation are sometimes thought of synonymously, but innovation includes the implementation of creative ideas, while creativity does not (Amabile, 1996; Hulsheger, Anderson, & Salgado, 2009; Woodman, Sawyer, & Griffin, 1993). In the next three sections, I describe important characteristics of research that addresses creativity by conceptualizing it as a creative process or as resulting in creative outcomes, and I discuss the different task types that are typically seen in creativity research.

Creative Process

The creative process is often theorized about, but less often tested. Several researchers have conceptualized creativity as a process that individuals and groups use to generate creative ideas (e.g., Csikszentmihalyi, 1997; Drazin, Glynn, & Kazanjian, 1999; Harvey & Kou, 2011; Mumford, Mobley, Reiter-Palmon, Uhlman, & Doares, 1991). This process perspective has led many to postulate that creative thought is composed of multiple distinct modes of thinking and observable behaviors (Amabile, 1996; Baughman & Mumford, 1995; Drazin et al., 1999). One broad characterization of the creative thinking process casts it into divergent and convergent thinking (Guilford, 1950; Runco, 1991; Torrance, 1969). *Divergent thinking* refers to thought that ranges across various domains or categories of knowledge instead of thinking in predictable ways, and often includes search for many varied and imaginative ideas and problem solutions (Guilford, 1967; Runco, 1991). *Convergent thinking* is reasoning or problem-solving "in which cognitive operations are intended to converge upon the single correct answer to a problem" (Smith & Ward, 2012). Using this broad characterization, creative ideas are generated via divergent thinking, and then evaluated and selected with more convergent thinking (Milliken, Bartel, & Kurtzberg, 2003; Staw, 2009).

Early creativity theorists proposed that the creative process plays out as an ordered sequence of these thinking behaviors, however, there is no strong empirical evidence that this is so (e.g., Eindhoven & Vinacke, 1952; Patrick, 1937). This lack of evidence prompted researchers to revise assumptions and postulate that creative thinking might just as plausibly involve an iterative process that may cycle back and forth between the different thinking modes (e.g., Brown, Tumeo, Larey, & Paulus, 1998; Nijstad & Stroebe, 2006; Skilton & Dooley, 2010). Montag, Maertz, and Baer (2012) recently summarized a collection of the most-cited creativity process models and articulated a general framework that captures the important similarities among them. This general framework contains thinking behaviors that align with the concepts of divergent and convergent thinking, including problem formulation/definition, preparation/information gathering, idea generation, and idea evaluation/validation. For example, problem formulation, information gathering, and idea generation are often conceptualized to entail divergent aspects of thought, while idea evaluation is thought to involve convergent thought characteristics (Montag et al., 2012). One perspective that has developed places high value on divergent thinking, because divergent thinking is assumed to promote ideational variety and thus establishes the potential for creative output (Staw, 2009).

Creative Outcomes

Many creativity studies conducted within organizations have evaluated creative outcomes as indicators of group creativity (Shalley, Zhou, & Oldham, 2004), and this is true for lab-based creativity research as well, including some brainstorming studies (Diehl & Stroebe, 1987; Mullen et al., 1991). Creative outcomes are often evaluated in terms of novelty, usefulness, and flexibility (Amabile, 1996).

Novelty reflects the uniqueness or rarity of a creative product (Amabile, 1996). When comparing and assessing multiple creative ideas, for example, novelty can be computed as mathematical infrequency. Novel ideas are relatively rare ideas. Even though novelty and creativity may be thought of synonymously, this proves to be a flawed approach. Judgments of novelty cannot discriminate the creative from the simply bizarre (Amabile, 1996). To differentiate the creative from the outlandish, judgments of usefulness are also required (Simonton, 1980).

Usefulness can be thought of as how well a creative response reflects appropriateness or feasibility (Amabile, 1996). There are several potential conceptual issues related to appropriateness and feasibility, and their relative significance may depend on the particulars of the creative problem or task for which responses are generated. For example, appropriateness judgments may depend on whether there are subjective but widely accepted norms involved in meeting the goals and constraints of the creative task. Feasibility can be interpreted as whether a solution to a creative problem could realistically be accomplished from a technical or other objective standpoint (e.g., a solution idea that incorporates magic or extrasensory perception might garner a low feasibility judgment). To the extent that these goal and constraint issues seem satisfied by a creative idea, the subjective judgments of usefulness are established.

A related but distinct characteristic is *flexibility*, the extent to which creative products range across multiple, diverse knowledge domains. Flexibility is often viewed as evidence of divergent thinking (Guilford, 1950).

Creative Task Types

Creative tasks are heuristic, which means there is no obvious path to a solution. In some cases, researchers have used *intellective* tasks (Laughlin & Ellis, 1986), where study participants must presumably use creative thinking to come up with a singular, *demonstrably correct* solution to a problem (e.g., Duncker, 1945). However, the choice of task in these types of tests requires that researchers use some a priori ideas about what constitutes the creative thinking process, and the validity of this methodology has been criticized on this account (Amabile, 1996).

Creativity researchers have also used judgmental, open-ended tasks that do not have a singular, correct answer (e.g. Baer, Leenders, Oldham, & Vadera, 2010; Baer, Oldham, Jacobsohn, & Hollingshead, 2008; Goncalo & Duguid, 2012; Goncalo & Staw, 2006; Nijstad, Stroebe, & Lodewijkx, 2002, 2003). For example, Gino, Argote, Miron-Spektor, and Todorova (2010) used a task that required participants to construct multiple origami figures. Such tasks provide a suitable environment for creative thinking and simulate the types of problem situations common in work organizations. For this dissertation, I conform to this latter approach and consider creativity in open-ended tasks with many possible solutions.

Two primary literature reviews are next. First, I review and summarize creativity in groups. This includes the brainstorming literature, which covers idea production at the group level of analysis. The review also includes group level creativity studies taken mostly from the organizational behavior literature. Second, I review the literature on analogical reasoning, which is primarily composed of cognitive science studies at the individual level of analysis.

GROUP CREATIVITY

Brainstorming

The central question in the brainstorming literature is: Does group interaction help or hinder the group-level production of creative ideas? Alex Osborn came up with a prescriptive set of group interaction rules that was intended to increase a group's ability to produce creative ideas (Osborn, 1953, 1963). The rules were 1) Criticism is ruled out; 2) "Free-wheeling" is welcomed; 3) Quantity is wanted; and 4) Combination and improvement are sought. The past sixty years have seen Osborn's rules for group idea generation put to the empirical test.

The primary measure of interest in brainstorming studies is *fluency*, the number of ideas produced. As a measure of idea production (or, "ideation"), fluency assesses what is essentially an additive task (Steiner, 1972) – that is, the number of ideas produced by a group's members are summed to calculate performance. Additive tasks like this possess the advantageous characteristic that they can be used to examine group synergy. In order to assess the synergistic effects of group interaction, studies typically compare interacting groups with "nominal" groups, which are randomly composed of non-interacting individual brainstormers. Nominal group fluency is the sum of the ideas generated (individually) by each of its members. Synergy is confirmed when interacting groups produce a greater number of ideas than do nominal groups.

The first experiment to test the effects of brainstorming showed, surprisingly, that group interaction significantly *decreased* idea production (Taylor, Berry, & Block, 1958). Many replications followed, and a meta-analysis by Mullen and colleagues (1991) provided conclusive summarized empirical evidence of the negative effect of group interaction on ideation. Over the past 20 years, researchers have tried to explain this negative effect, and in some cases, counteract it. The four most common explanations for this so-called *production loss* in brainstorming are evaluation apprehension, social loafing, performance matching, and production blocking. Below, I review the evidence for each explanation.

Evaluation apprehension

Even though one rule of brainstorming instructs group members to refrain from criticizing the ideas of others, people may still fear a negative judgment of their ideas and withhold them (Diehl & Stroebe, 1987). This fear of negative evaluation can lead to a reduction in fluency for interacting groups compared to nominal groups, because in nominal groups the members produce ideas in solitary isolation, and thus no immediate evaluation by others is possible.

Some evidence exists for evaluation apprehension. For example, Collaros and Anderson (1969) found that group brainstorming members were more unwilling to provide their ideas when they believed others in the group were experts in the subject domain at hand. In another study, Diehl and Stroebe (1987) found that when brainstormers were told their performance was being monitored and evaluated, their ideation performance tended to decrease. These results indicate that evaluation apprehension does appear to reduce the production of ideas in brainstorming groups.

Social loafing

When it is unclear how to identify the contributions of individual group members in the group output, this may result in a motivation loss called *social loafing* (Latane, Williams, & Harkins, 1979). In the interactive brainstorming context, when members do not have a way to attach individual ideas to those who contributed them, social loafing may arise. Perhaps ironically, Osborn (1953) recommended that contributors' names *not* be associated with the ideas they provide, possibly priming conditions for social loafing where this advice is followed.

Empirical evidence indicates that social loafing may indeed affect brainstorming groups. Harkins (1987) found in an experiment that brainstorming participants whose output could be evaluated outperformed participants whose output could not be evaluated. Also, Williams and Karau (1991) found that brainstormers who expected individual evaluation generated more ideas than those expecting a group evaluation, and that these main effects were moderated by expectations of coworker performance.

Performance matching

Brainstormers who work together are in a position to observe their coworkers' contributions. In particular, members may perceive an implicit group norm about the expected rate of idea production, by observing the idea contributions of other members. This perception may push members to converge upon a similar rate of contributions, a phenomenon termed *performance matching*. Brainstormers who work alone do not have this information and are therefore unaffected. This leads to a prediction that individuals in interacting ideation groups should each contribute about the same number of ideas during a brainstorming session, while members of nominal groups will vary more in terms of the number of ideas they generate. This logic leaves open the possibility that performance matching norms might increase interacting groups' idea production compared to nominal groups, rather than decrease it.

However, Paulus and Dzindolet (1993) proposed that the initial conditions of interacting brainstorming groups, including negative productivity effects of turn-taking, social loafing, and evaluation apprehension, might reduce the rate of contributions at the beginning of a brainstorming session. This initial lowering of the idea contribution rate would then establish a group norm and allow performance matching effects to take over and maintain the lowered rate of production. In a series of three brainstorming experiments (1993), they consistently found that members of interactive groups tended to contribute about the same number of ideas as the other members of their group, i.e., the intra-group variance for member fluency was rather low. By contrast, members of nominal groups exhibited more intra-group variance in the number of ideas contributed by members. Also, average nominal group fluency was greater than average interacting group fluency, replicating the classic brainstorming finding. Camacho and Paulus (1995) replicated this result in the first of two brainstorming experiments. These studies seem to support the rationale behind the performance matching explanation for lower idea production in interactive brainstorming, versus nominal, groups.

Production blocking

One assumed advantage of group interaction is that hearing others' ideas stimulates further creative thinking (Dugosh, Paulus, Roland, & Yang, 2000; Osborn, 1953). This *cognitive stimulation* represents a fundamental mechanism by which interacting groups might benefit from the group context and achieve synergy in producing creative responses. However, during ideation members must take turns contributing ideas to avoid communication problems, and waiting to take turns is the root cause of *production blocking*. Members who think of an idea, but must hold it in working (short-term) memory until they can contribute it, run the risk of forgetting it. Also, the load placed on working memory by the simultaneous requirements of remembering the idea, seeking an opportunity to contribute it, and actively listening to other members compromises the ability to continue searching long-term memory for more ideas. Search is temporarily put on hold, due to the load placed on working memory. Individual brainstormers are thus believed to run a lower risk of forgetting, and are able to conduct more long-term memory search, compared to members of interacting groups. This hypothetically leads to a fluency advantage for nominal group members compared to interacting groups. Production blocking may therefore tend to counteract the theoretical benefits of cognitive stimulation.

Researchers have tried to establish the conditions under which either production blocking or cognitive stimulation dominate during group brainstorming. For example, Diehl and Stroebe (1987) conducted an experiment contrasting interacting groups with nominal groups, and their results replicated the fluency advantage of nominal groups. But, they also created three special nominal group conditions where individuals had to watch signal lights that indicated when other members of their "virtual" group were talking. In two of these conditions, individuals were told they had to wait until the lights signaled they could contribute an idea, simulating the turn taking of interacting groups. In the third special condition, individuals watched the lights but were told to contribute their ideas as soon as they thought of them. In the two special conditions where individuals had to wait, nominal group fluency was similar to that of interacting groups. But in the special condition with no waiting, nominal groups performed as well as the regular nominal groups with no signal lights. These results are interesting because the study design separated the social factors encountered in interacting groups from the purely cognitive effects of production blocking. It also showed that production blocking seemed to account for the major portion of the negative fluency effect for interacting groups. These findings have led researchers to focus on production blocking as one of the more significant theorized mechanisms of process loss for brainstorming groups.

A silver lining: Cognitive stimulation during brainstorming

There is also empirical evidence that cognitive stimulation can arise in brainstorming groups, but certain conditions must exist. Employing a process called *brainwriting*, where group members do not speak but instead write ideas on paper and pass their ideas around to each other, Paulus and Yang (2000) found that four-person groups in a brainwriting condition produced significantly more unique ideas than did nominal groups. Further, when participants continued to generate ideas individually in a subsequent ideation period, those who had been exposed to the ideas of others in the brainwriting condition produced nearly twice as many unique ideas compared to those who had no exposure to others' ideas. This positive effect suggests that members were indeed cognitively stimulated by the ideas of others. Studies of electronic brainstorming, which represents a high-tech variation on brainwriting by using computing equipment instead of paper slips, have produced similar findings (Dennis & Williams, 2003).

Brainwriting and electronic brainstorming research is important because it shows that groups do have the potential for intermember cognitive stimulation that pushes ideation performance beyond that of individual brainstormers. A possible drawback of these approaches is that in order to achieve this boost in production, interaction and communication between members must be practically eliminated. If communication processes are needed for other aspects of the group creative process, (e.g., interactive memory cueing or other collaborative processes), the conditions required for brainwriting and electronic brainstorming may restrict these potentially beneficial group processes.

Summary: Brainstorming

Brainstorming research reveals how group interaction can negatively affect the group-level production of ideas, but recent studies also suggest that under certain conditions, cognitive stimulation is possible. If cognitive stimulation arises as a result of intermember interaction, it may provide advantages for creative groups. Eliminating or otherwise overcoming the bad effects of interaction (e.g., evaluation apprehension) while preserving or enhancing its cognitive benefits seems to be a prescriptive route for heightened group creativity.

Next, I review and summarize group-level creativity studies that fall outside the brainstorming paradigm, primarily in organizational behavior studies.

Group creativity in organizational behavior

Like the brainstorming literature, the studies reviewed next examine creative outcomes at the group level of analysis. However, the studies are not limited to laboratory tests of idea production (fluency) using simple ideation tasks, and they also tend to examine group level compositional and emergent state variables that may affect group creative processes and outcomes. The number of studies devoted to examining open-ended group creative outcomes is less than the number of brainstorming studies, so obvious trends and patterns in findings are more difficult to discern. The following review is organized broadly according to antecedent and contextual variables that have an impact on group creativity.

Member composition and leader characteristics

Several researchers have argued that the composition of group member characteristics matters for group creativity (Milliken et al., 2003; Shalley, 2008; Somech & Drach-Zahavy, 2011), and some empirical studies support this claim. Chirumbolo and colleagues (2005) found that groups composed of members with a high need for closure produced fewer unique ideas and less creative ideas compared to groups composed of members with a low need for closure. They also found evidence that high need for closure groups spent less time in discussion and engaged in less elaboration of their initial solution, compared to low need for closure groups. In a study of 47 MBA student dyads who interacted virtually during task execution, Martins & Shalley (2011) found that member age difference was positively associated with group creativity when process conflict was low, when members participated more equally in discussion, when members spent more time establishing rapport, and when members had about the same experience with virtual communication technology (e.g., email, chat rooms, etc.). However, member age difference was negatively associated with group creativity when process conflict was high, when members participated less equally in discussion, when members spent little time establishing rapport, and when members had very different levels of experience with virtual communication technology. In another study, Hoever, van Knippenberg, van Ginkel, and Barkema (2012) found that perspective taking positively moderated the association between diversity of perspectives and team creativity. They also found that perspective taking moderated the association between diversity of perspectives and information elaboration, and that information elaboration mediated the interactive effect of diversity and perspective taking on team creativity. Baer, Oldham, Jacobsohn, and Hollingshead (2008) found that groups exhibited high creativity when they included more high extraversion, high openness to experience, and low conscientiousness members, and when members shared a sense of creative confidence in the group. Together, the above studies suggest that similarities and differences in member characteristics can indeed affect group creativity, but they also show that group interaction and processes are important as well.

Group processes were the focus of a study of sales teams by Sung and Choi (2012). Sung & Choi (2012) found that team knowledge utilization in insurance firm teams was positively associated with team creativity. This association was stronger when members experienced higher environmental uncertainty. Contrary to the authors' predictions, leaders' systematic cognitive style (i.e., preference for rules, procedures, etc.) was just as important for team creativity as was an intuitive cognitive style. This study suggests that in order for teams to realize the creative potential of their collective knowledge, a strong intuitive *or* a strong systematic cognitive style in team leaders may be beneficial.

Culture and Norms

Group culture and norms may affect group creativity (e.g., Flynn & Chatman, 2001), but empirical findings hint that the relationship between these variables is not straightforward. Goncalo and Staw (2006) tested direct and interactive effects of group culture (individualistic vs. collectivistic) and the nature of task instructions on group creativity. They found a consistent pattern of results showing that individualistic groups were more creative than collectivistic groups when they were instructed to be creative, but not when they were instructed to be practical. In a related experiment, Goncalo and Duguid (2012) found that groups composed of highly creative members and those composed of less creative members responded to group norm conformity pressure differently. Groups with highly creative members were most fluent and most original when norms were individualistic and conformity pressure was low. Conversely, groups with less creative members were most fluent and original when there was high pressure for individualism. This study shows that the combination of norms and conformity pressures that leads to group creativity depends upon individual differences in member creativity. This study further suggests that groups of creative "superstars" may benefit from a different set of working conditions compared to groups composed of less naturally creative members.

Membership change

Group membership change potentially introduces disruptions to group knowledge, processes, and performance (for reviews, see Argote & Kane, 2003; Levine & Choi, 2004), but membership change can also lead to an infusion of new ideas and stimulate divergent thinking and reflection upon the way group members approach their tasks (Levine, Choi, & Moreland, 2003; Staw, 1980). Baer, Leenders, Oldham, and Vadera (2010) found some support for interactive effects of membership change and intergroup competition on group creativity. Specifically, groups that experienced membership change had a U-shaped relationship between intergroup competition and group creativity. Groups that experienced no membership change had a positive relationship between intergroup competition and group creativity. Choi & Thompson (2005) found that creativity was higher when groups experienced a membership change, compared to groups that did not. Further, they found evidence that the increase in group creativity was not purely due to the ideas that new members brought with them, but that the creativity of "oldtimers" was enhanced by social interaction with the new members.

Task and task experience effects

Pearsall and colleagues (2008) found that when the group task activated gender faultlines, this negatively affected team fluency and the creativity of team ideas. They also found that emotional conflict partially mediated the negative effects of activated gender faultlines on team fluency. These findings suggest that diversity in creative teams may be detrimental if faultlines are present and if the team engages in a *task* for which diversity salience may activate the faultlines. Brophy (2006) found evidence that, compared to nominal groups, interacting groups tended to perform better on multi-part, complex creative tasks. Consistent with the brainstorming literature as a whole, he also found that nominal groups tended to outperform interacting groups when members engaged in a relatively simple ideation task. This study introduces a potential boundary condition to the brainstorming findings that consistently show an ideation advantage for nominal groups, i.e., as the complexity of the creative task increases beyond very simple ideation problems, perhaps group interaction becomes more valuable for group creativity.

In a study where groups learned how to produce origami objects, Gino and colleagues (2010) found that direct experience on an initial task led to higher group creativity on a subsequent, similar task, compared to indirect or no task experience. Indirect task experience was instilled in some groups by allowing them to watch a video of another group performing the origami task. The researchers found that transactive memory systems (TMS), presumably built and strengthened during the initial shared task experience, mediated this effect. Also, groups that experienced a membership change between two trials of the task produced creative products with higher component divergence, an indicator of divergent thinking, compared to groups that experienced no membership change. These findings seem to line up with those of Choi and Thompson

(2005), who found that membership change stimulated increases in both group fluency and group flexibility.

Interestingly, although TMS was associated with overall group creativity in this study, it was not associated with component divergence, an indicator of divergent thinking. These findings leave the role of TMS for group creativity at issue. It may be that the efficiencies in group coordination brought about by TMS may help in creative tasks where some execution or tangible product creation is required. TMS is expected to help groups during this execution phase, when task labor can be divided up among members based on what they know and what they are good at (Moreland, 1999). However, these findings call into question whether TMS enables divergent thinking in the exploratory phases of creative thinking.

Summary: Group creativity

This research on group creativity is smaller and relatively recent, compared to the previously reviewed literature on brainstorming. Though it covers a variety of concepts, some general themes are hinted at. First, aggregated individual characteristics (such as personality variables or need for closure) may be important for group creativity, but their effects on group creativity are often moderated by the effectiveness of group processes. Second, cognitive stimulation seems to be enhanced and more beneficial for group creativity when it involves not just mere exposure to member ideas, but rather when it occurs via social interaction with other group members. This stands in contrast to some recommendations derived from brainstorming studies that argue for the elimination of social interaction in order to prevent production blocking and other undesirable social effects like evaluation apprehension (Paulus & Yang, 2000). Also, the nature of creative tasks seems to matter. Different creative tasks generate variance in the extent to which group members benefit from collaboration and idea sharing as they work to creatively solve problems. These collaborative group processes are often not required for the simplest of brainstorming tasks (e.g., “think of uses for a brick”), where members may contribute individually-generated, complete solution ideas in rapid succession without pausing to evaluate, assess, or build upon them (indeed, evaluation is discouraged if brainstorming rules are used).

A recent meta-analysis is also relevant. Hulsheger, Anderson, and Salgado (2009) collected and meta-analyzed team-level predictors of innovation in organizational studies. They drew a couple of conclusions, as follows: 1) team processes (e.g., cohesion) seem to display stronger links to individual and team innovation than team compositional inputs (e.g., demographic diversity); 2) effect sizes in the literature are widely overestimated due to common-source bias in a majority of studies, generated by using self-report data for the criterion variables measuring individual and team innovation. They characterize the second conclusion as representing “a fundamental misunderstanding in our knowledge base.” However, the finding that team processes tend to be important predictors of individual and team innovation indicates that the same might be true for group creativity. Given that creativity is a “subprocess of innovation” (Hulsheger et al., 2009), this meta-analysis indicates that further study of group creative processes is important for understanding group creativity and for understanding individual and team innovation in organizations.

Next, I review the literatures on individual creative cognition and on analogical reasoning. There are reasons to believe that analogical reasoning may help creative groups, through its effects on idea generation and evaluation. Analogical reasoning consists of cognitive processes that may provide a complementary balance of abstract and systematic thought that is beneficial for group creativity. Below, I first briefly review the relevant research on individual creative thinking, to introduce concepts that remain relevant in a group context. Next, I describe analogical reasoning and summarize the main findings from the analogical reasoning literature, much of which focuses on the individual level of analysis.

CREATIVE THINKING AND ANALOGICAL REASONING

A large part of what is known about creative thinking comes from individual-level studies in cognitive science. Below, I concisely review and summarize the applicable research on individual creative thinking, before moving on to a literature review of analogical reasoning.

Individual creative thinking

A few key concepts emerge from studies of individual creative thinking. The first is that individuals are prone to fixation on the superficial details and features of specific examples they think of, or are otherwise exposed to, and these features make their way into the ideas and potential solutions that individuals generate. For example, in two different design studies, individuals who were shown examples of design solutions tended to incorporate features of those examples into their designs, even when they were told the features were prohibited from inclusion (Jansson & Smith, 1991; Smith, Ward, & Schumacher, 1993). Similar results are found in studies of word fragment problems (e.g., Smith & Tindell, 1997), where subjects were often unable to complete a word fragment (e.g., CHAR_T_) when they are first primed with an incorrect word (CHARTER) that is similar to the correct answer (CHARITY). Fixation effects like these tend to block individuals' thinking processes from accessing ideas from a variety of different knowledge domains, and this reduction in divergent thinking can decrease creativity.

The second key idea is that creativity often benefits when non-obvious elements, potentially from different knowledge domains, can be combined into a solution. The theory of *remote association* (Mednick, 1962) characterizes creative thinking as an associative cognitive process, and proposes that creativity involves retrieving a semantically *remote* associate of a stimulus. Remote association is theorized to result in idea combinations that would not arise when thinking of each associative element separately (Kunda, Miller, & Claire, 1990). The novelty of these new ideas, resulting from the retrieval and combination of ideas from different knowledge domains, can help increase creativity.

Another insight is that complete randomness or blindness in the search for solutions may not be the most efficient or effective method of thinking for solving creative problems. Darwinian models of creativity (Campbell, 1960; Simonton, 1999) emphasize blind variation of ideas until, by lucky circumstance, a novel and useful idea emerges. This leads to the proposition that the chances for creativity can be increased by generating many ideas, i.e., the more ideas, the better. However, there is some lingering theoretical debate about the nature of blind variation and its similarity to complete generative randomness. The current stance among theorists is that pure randomness in the variation process is not always required, nor is it most effective, for creativity (Simonton, 2011a, b; Staw, 2009; Sternberg, 1999). What seems to emerge from this literature is the broad notion that creative thinking may benefit from a balance between a directed, algorithmic process and some element of randomness in the search for ideas.

Summary: Individual creative thinking

The above review suggests there are at least three things that impact individuals' creativity. First, fixation on irrelevant or surface-level features of a problem decreases an individual's ability to develop creative solutions. Second, combining non-obvious elements from different domains may increase the novelty of creative solutions. Finally, a balanced search strategy that combines randomness and algorithmic directed search is likely to be of benefit to individual creative thinking.

In the section that follows, I review the research on analogical reasoning. Analogical reasoning has been proposed as potentially valuable for generating creative problem solutions (Markman et al., 2009; Smith & Ward, 2012). As Gentner and colleagues put it, analogical reasoning may be an engine of creativity "…in part because it provides a fair degree of structure while inviting some alteration." (Gentner et al., 1997). Analogical reasoning incorporates abstractness of thought that arises from comparing relationships between corresponding aspects of problems and potential solutions. It also requires some level of systematic thought and may stimulate an evaluative mindset that subsequently produces higher solution usefulness. As such, analogical reasoning may overcome barriers to creative thinking such as fixation, and at the same time, facilitate the consideration of different domain elements and guide the effective search for creative solutions.

Analogical reasoning

Analogical reasoning, as a strategy for solving complex problems, is based on the idea that one can often use previous knowledge to solve a novel problem. According to Gentner (2003) analogical reasoning invites new inferences based on comparisons between specific cases or problems, such that prior knowledge about one case or problem can be used to infer new information about another.

Analogical reasoning has been widely studied as a means to solve problems with intellective characteristics (Catrambone & Holyoak, 1989; Chan, Paletz, & Schunn, 2012; Gick & Holyoak, 1983; Holyoak, 2012; Kurtz & Loewenstein, 2007; Reeves &

Weisberg, 1994; White & Alexander, 1986). For example, Gick and Holyoak (1980) found that individuals were able to transfer knowledge from one story to a problem situation using analogical reasoning, producing the solution the experimenters were looking for. Also, Bassok and Holyoak (1989) found that individuals who learned algebraic principles to solve arithmetic problems were able to transfer those principles to generate demonstrably correct solutions for analogous physics problems. In another study, Novick (1988) found that analogical transfer for experts and novices working on mathematical problems with correct solutions exhibited some differences due to variations in surface and structural similarities. Specifically, surface features seemed more problematic for novices than for experts, when trying to use analogical reasoning on the math problems.

An example: Using analogical reasoning to solve a novel problem

Some of the most popular analogies in the analogical reasoning literature are variations of the Duncker radiation problem (Duncker, 1945). I describe the problem here to help clarify terminology used in the analogical reasoning literature and to illustrate the key mechanisms underlying the effects of analogical reasoning for creative problem-solving.

For a typical study task involving the Duncker radiation problem, study participants (who do not have prior specific knowledge of cancer therapies) are tasked with solving a novel problem: destroying a cancerous tumor without damaging the surrounding healthy tissue. As a therapy, radiation is not only strong enough to damage a cancerous tumor, but also strong enough to damage healthy tissue. Using analogical reasoning, study participants are able to solve this novel problem (referred to as the *target problem)* by comparing the target problem to one or more other problems for which a solution is known (referred to as *source analogs).* Gick and Holyoak (1980) developed several source analogs intended to aid in solving this target problem. One source analog was called the Attack-Dispersion story, in which a military general has a goal of capturing a fortress. Many roads radiate outward from the fortress, but all the roads are mined with explosives such that any large group of soldiers will be unable to pass. The general overcomes this constraint and achieves his goal by dividing his army into many small groups, and sends each small group up a different road. The small size of each group prevents the mines from exploding. In this way, the general is able to send his whole force toward the fortress, where they converge and succeed in capturing it.

Comparing this source analog problem and solution to the radiation (target) problem, allows one to infer a solution to radiation problem. Implied in the analogical reasoning process is the recognition that the target and source problems are structurally similar. In this case, the structural similarities between the radiation (target) problem and the Attack-Dispersion story (the source analog) can be summarized as follows: 1) the tumor and the fortress are objects to be captured/destroyed; 2) the radiation and the soldier forces are the means of destruction; 3) the strategy of sending the whole destructive force against the target from one direction is not an option, due to an undesirable outcome it would produce. Given these structural similarities, it is likely that the solution to the Attack-Dispersion problem (divide up the destructive military force and send it at the fortress from different directions) can be applied to the target radiation problem. Specifically, one solution to the radiation problem is to “divide up” the radiation therapy (by using weaker rays) and send the radiation to the tumor from different directions. In that way, the tumor receives the required therapy and healthy tissue is preserved. It is important to note that the target problem and the source analog story *are not similar in terms of the surface features of objects in the scenarios*, i.e., one involves soldiers and a fortress and the other includes radiation and a tumor. But, the relationships between the elements of each story are very similar. Recognizing *relational structure similarity* between target and source analogs is fundamental to analogical processing.

Analogical Processing

There are several theoretical models of analogical processing, and they share commonality in terms of their major component subprocesses (Gentner, 1983; Holyoak, 1985; Holyoak & Thagard, 1989; Reeves & Weisberg, 1994). Usually, a target problem or situation cues an individual to *retrieve* a potentially beneficial source analog from memory. Then, a *mapping* can be established between the source analog and the target, using the similarities in relational structure to guide the mapping. The mapping enables a process of *drawing new inferences* about the target situation, based on knowledge about the source analog. In problem-solving, this usually involves making inferences about a target problem solution based on the known solution to the source analog problem. Individuals who think through these steps are likely to *develop a generalized schema* that represents an abstract category of problems or situations, of which the target and source are examples. A considerable amount of empirical research examines these analogical subprocesses, and in next few sections, I review this literature.

Analogical subprocess: Source analog retrieval

Gick and Holyoak (1980) found that individuals often do not notice source analogs that could be used to solve a target problem. The difficulty of noticing and retrieving source analogs has been documented by many others (e.g., Gentner, Rattermann, & Forbus, 1993; Holyoak & Koh, 1987; Spencer & Weisberg, 1986). Markman, Taylor, and Gentner (2007) found that people have more success retrieving relationally-similar source analogs when they are presented in spoken form as opposed to written form. Other research has shown that when individuals are given an exemplar cue, they tend to retrieve source analogs that are from the same knowledge domain as the cue, instead of retrieving source analogs from different knowledge domains (Keane, 1987). This research points to the relatively large cognitive effort required to retrieve source analogs from memory. Retrieval of source analogs is a search process through long-term memory, an open-ended task that can require great sustained cognitive effort and is subject to the nature of the search cues used.

Analogical subprocess: Mapping

Analogical mapping involves comparison processes between source and target analogs (Gentner, 1983; Gentner & Markman, 1994; Markman & Gentner, 1993, 1996). Using information about how elements relate to each other in both source and target analogs, and using comparison processes to identify similarities in those relationships, people are often capable of successful mapping between analogs, even when superficial similarity between corresponding elements is low (Gentner & Gentner, 1983; Gick & Holyoak, 1983). For example, Gick and Holyoak (1980) found that when participants were given a hint to use a source analog, they solved the target problem with very high rates of success (>90%), indicating that mapping between the source and target presented no great difficulty for participants, once they had the source analog in mind.

Analogical mapping is subject to limitations on working memory. Waltz and colleagues (2000) found that individuals asked to map objects between pictorial scenes while simultaneously performing another task (e.g., producing random numbers) tended to use more superficial object feature similarity rather than relational similarity in their mappings. In another study, Tohill and Holyoak (2000) found that an anxiety manipulation similarly affected individuals' mappings, skewing them more toward the use of perceptual similarity at the expense of relational structure similarity. These findings suggest that individuals must have adequate working memory available in order to engage in analogical mapping.

Analogical subprocess: Solution inference

Solution inference is often the main point of engaging in analogical reasoning (Holyoak, 2012). It is through the inferences drawn from analogical reasoning that progress toward a target problem solution is usually achieved. After source:target mapping is complete, inferences may be drawn to form new propositions about the target problem itself. These inferences involve looking for ways that the solution approach taken in the source analog might be translated or transferred into a similar type of solution approach for the target problem. People are generally proficient at analogical inference, once mappings are established (Gick & Holyoak, 1980). However, analogical inference is not guaranteed to produce good solutions. If mapping is difficult or if it performed inaccurately, errors in solution inference may arise (Bassok & Holyoak, 1989; Bassok & Olseth, 1995; Reed, 1987).

Analogical subprocess: Generalized schema induction

The comparison processes involved in analogical reasoning can lead to the formation of an abstract schema, a generalization that serves to categorize and represent the relational structure shared by multiple analogs. Once formed, schemas are theorized to facilitate subsequent source analog retrieval, mapping, and inference (Holyoak, 2012). Using as few as two analogs in the comparison process, lab studies have produced evidence of abstract schema formation and the subsequent advantage in problem-solving they provide (Catrambone & Holyoak, 1989; Gick & Holyoak, 1983).

Even though comparing two source analogs promotes schema formation, there is also evidence that comparing additional examples promotes even more effective schema abstraction (Brown, Kane, & Echols, 1986; Brown, Kane, & Long, 1989; Catrambone & Holyoak, 1989). For instance, Loewenstein, Thompson, and Gentner (1999) found that when individuals compared multiple analogous examples of negotiation techniques, they formed higher quality schemas and then performed better in a real negotiation, relative to those who did not do multiple comparisons. Interestingly, negotiation performance did not depend on a good a priori understanding of either of the examples used to generate the schema, implying that deep expertise in the subject domain of the examples may not be required in order to produce high quality abstract schemas.

These studies generally suggest that when people engage in comparison processes between target and source analogs and think about the underlying relational structure of both analogs, it enhances the quality of the abstract schema formed, and subsequently increases the chances that knowledge can be transferred from memory to help solve problems effectively. Abstract schemas facilitate knowledge retrieval and the subsequent mapping and solution inference processes of analogical reasoning.

Given the potential problem-solving benefits of developing an abstract schema, quite a bit of research has focused on the factors that make abstract schema development and use more likely (e.g., Catrambone & Holyoak, 1989; Gick & Holyoak, 1983; Novick & Holyoak, 1991; Ross & Kennedy, 1990). Some recent research has shown that an abstract schema does not necessarily have to be stored in memory ahead of time in order to facilitate the retrieval of source analogs from memory. Specifically, Gentner. Loewenstein, Thompson, and Forbus (2009) replicated the results of Kurtz and Loewenstein (2007) and showed that people who reframed a target problem in more abstract terms, by comparing problem examples, were more effective in retrieving useful knowledge from memory, compared to people who did not form an abstract understanding of the target problem. This recent research is interesting because it suggests that abstract schemas do not need to exist in memory *a priori*, but rather that abstract schemas can be developed "on the fly," when an individual is thinking about and comparing versions of the target problem. These results are particularly relevant for creativity, because divergent thinking, which depends vitally on search for ideas in memory, is a critical process for establishing creative potential (Staw, 2009). Moreover, developing abstract schemas in the moment is likely to be relevant for and helpful to interacting individuals, who may be able to build upon one another's ideas to infer new abstract understandings of the problem and develop more creative problem solutions as a result.

Analogical reasoning in groups

There are few studies that examine analogical reasoning in groups. One exception is Lewis, Lange, and Gillis (Lewis, Lange, & Gillis, 2005), who drew from analogical reasoning theory to explain how knowledge transfer across different but related tasks might occur. They argued and found evidence that interacting groups with a developed TMS who performed two similar tasks gained a better abstract understanding of the task domain and performed better in a knowledge transfer task, compared to groups without a TMS. Other findings from the study indicated that groups were more likely to develop an abstract understanding of the task domain once they had performed two tasks together – performing one task was not sufficient for a collective abstract schema to develop. This finding is consistent with findings at the individual level, which suggest that multiple analogs (and associated comparison processes) help individuals develop more useful abstract problem schemas.

A few other studies from the engineering design literature take a more qualitative approach to analogical reasoning in collectives. For example, Christensen and Schunn (Christensen & Schunn, 2007) gathered five months of video data from meetings held by a medical plastics engineering design team. They found that the use of physical prototypes during meetings often coincided with analogies that stayed within knowledge domains closely related to the prototype, indicating that designers may have been suffering from fixation while their collective attention was focused on the prototypes. In another study, Ball and Christensen (2009) studied transcripts of engineering design meetings and found that analogies often coincided with expressions of design uncertainty, and seemed to be intended as a means to resolving uncertainty. Also, Dahl and Moreau (2002) analyzed verbal protocol transcripts of four professional designer dyad teams who worked for one hour on the design of a mobile dining device. The researchers produced qualitative state diagrams that mapped the flow of conversation for each dyad, and found a correlation between the number of analogies mentioned and the originality of the designs produced by the teams.

This brief review of analogical reasoning in groups shows that little exists from which solid inferences can be drawn about how analogical reasoning may help groups with creative problem solution tasks. The study by Lewis and colleagues (2005) is a rare example of incorporating analogical reasoning and group cognition. Importantly, their study suggests that analogical reasoning can occur in a group context, and that the development of collective abstract schemas can improve performance on different but related tasks. Other, qualitative studies show that design groups do use analogical reasoning, but clear benefits for group creativity are difficult to discern. Group level comparisons of analogical reasoning with other types of reasoning strategies would seem to be a valuable addition to this literature, particularly if they generate insights about the associated effects on group creativity.

OVERALL SUMMARY

In this chapter, I have reviewed and summarized literatures on individual creative cognition, group creativity, and analogical reasoning. In the current section, I identify commonalities and complementary relationships that will motivate subsequent theory.

Studies of individual cognition generally indicate that fixation is a dysfunctional risk for people attempting to think of new and useful ideas. Superficial (semantic) features of solution ideas and problems seem to strongly attract attention and prevent wide-ranging, divergent thought. There is also much speculation about how a blend of structured and random thinking might be a balanced approach for creative cognition. Brainstorming studies have shown time and again that social/motivational and cognitive factors arise when people collaborate and use the brainstorming rules. One thing that stands out in this literature is that many studies have been run using the original brainstorming rules, or slight variations on them, and there does not seem to be a great deal of variety in the reasoning strategies that are tested in intact and nominal groups.

The organizational behavior literature on group creativity is relatively recent, and the work is spread around between examinations of individual differences, leadership, contextual factors (including culture and norms), task design, and very recent forays that use group learning and group cognition constructs to assess group creativity. This research is promising, and yet, the actual inter-member processes that play out when interacting groups attempt to produce creative outcomes are currently understudied.

The review of analogical reasoning raises a few pertinent issues that are related to creative thinking. Analogical reasoning requires comparisons of multiple analogs and recognition of their structural similarities. The cognitive processes involved in analogical reasoning can produce inferences and abstract schemas that can be quite beneficial for retrieving source knowledge and solving target problems. However, analogical reasoning is not necessarily guaranteed to produce functional results in all conditions. Challenges related to long-term memory search (i.e., source retrieval), the risk of fixation on superficial (semantic) features instead of abstract features, and the availability of adequate working memory can compromise the overall process of individual analogical reasoning.

Nonetheless, there may be reason to believe that retrieving past problems and solutions from memory by using analogical reasoning is a good way to tackle creative problem-solving (Markman & Wood, 2009), even for groups. Analogical reasoning has the potential to produce abstract problem schemas, and these have been shown to be effective in retrieving solution knowledge and in promoting subsequent mapping and solution inference. In a group context, collective abstract problem schemas may serve as useful cues for collective recall and may help fend off collective fixation on superficial features of the target problem. Collective abstract problem schemas may also help to guide effective long term memory search, and in so doing, increase chances that retrieved knowledge will produce useful solutions. In sum, analogical reasoning may widen the range of solution search and help groups leverage members' diverse knowledge, while still constraining the randomness of ideas that are seriously entertained.

Chapter 3: Theory and Hypotheses

GROUPS AS ANALOGICAL INFORMATION PROCESSORS

Collaborative creative groups possess valuable assets: the diverse knowledge held by members. However, unless that diverse knowledge is paired with an effective information processing strategy, creative groups may not effectively leverage their assets. Research shows that analogical reasoning can help individuals retrieve and use knowledge to solve intellective problems with demonstrably correct solutions (Holyoak, 2012). Analogical reasoning might be similarly advantageous as an information processing strategy for groups of individuals tasked with creative problem-solving where there is no demonstrably correct solution. Specifically, analogical reasoning may facilitate creative problem-solving in groups by: 1) stimulating divergent thinking, 2) preventing fixation on problem surface features, 3) reducing evaluation apprehension, and 4) encouraging sustained attention on the problem's goals and constraints. These effects combine to help groups retrieve and transform their diverse knowledge into creative problem solutions that exhibit heightened novelty, flexibility, usefulness, and overall creativity.

Analogical reasoning may also produce group synergy. Group synergy occurs when a group's output is superior to the output produced by the same number of non-interacting individuals (Larson Jr, 2010). When a group uses analogical reasoning as a problem-solving technique, it is likely to produce group synergy by 1) enabling a division of cognitive labor, 2) enhancing fixation avoidance, 3) supporting the retrieval and integration of diverse member knowledge, 4) stimulating interactive search guided by problem goals and constraints, and 5) enabling joint correction of reasoning errors. These synergistic effects tend to amplify the advantages of analogical reasoning for creative group outcomes, in the presence of group interaction. Below I develop arguments about how analogical reasoning can enhance creative problem-solving, conceptualized in terms of novelty, flexibility, usefulness, and overall creativity.

Analogical reasoning groups are likely to experience creative benefits as a result of the way the information processing strategy gives rise to abstract problem representations, and also because of its routine-like nature. As I argue below, analogical reasoning in creative groups is likely to stimulate divergent thinking, support fixation avoidance, and reduce evaluation apprehension. These effects tend to increase solution flexibility and novelty.

Stimulating divergent thinking. Analogical reasoning is essentially a dynamic process that feeds back on itself in open-ended creative tasks where one of the overall task goals is to generate numerous solutions to the problem. Problem schemas produced by the retrieve/map/infer/abstract sequence promoted by analogical reasoning serve as stimulative inter-member search cues that help retrieve additional member knowledge (source analogs) for subsequent iterations of the sequence (Holyoak, 2012). In the creative group context of idea generation, this repetitive, dynamic property of analogical reasoning renders it amenable to variation in the abstractness of the problem schemas, as the sequence repeats. Variation in problem schema abstractness is likely to stimulate the retrieval of knowledge from diverse knowledge domains and enhance divergent thinking, as I argue next.

When people compare a source analog with a target problem, one byproduct of this comparison process is a more abstract representation of the problem, i.e., an abstract problem schema (Gick & Holyoak, 1983). Increasing the number of comparisons often leads to increasingly abstract problem schemas (Brown et al., 1989; Catrambone & Holyoak, 1989). For an open-ended creativity task where one goal is to generate as many solution ideas as possible, multiple comparisons are likely for those who use analogical reasoning, and this repetition potentially results in numerous problem schemas that range from low to high levels of abstractness. Variation in problem schemas may also arise due to member differences in the way they naturally think in abstract ways. Analogical comparison processes will lead to varying perceptions of schema abstractness, simply due to these individual differences.

Each abstract schema serves as a memory cue for members of a group using analogical reasoning. The variation in cue abstractness is likely to correspond to the variety of knowledge domains that are stimulated in member memories (Christensen & Schunn, 2007; Holyoak & Thagard, 1995; Loewenstein, 2010), and also to the diversity of solution approaches represented in retrieved source analogs. Increased diversity in solution approaches leads to an increase in solution flexibility, and makes it more probable that unique and novel solution ideas are generated (Staw, 2009).

By contrast, groups whose members do not use analogical reasoning are less likely to generate abstract problem schemas at all. This deprives them of the divergent thinking advantages just described for dynamic variations in the abstractness of problem schemas produced by analogical reasoning groups.

Avoiding fixation. A related benefit of generating abstract problem schemas is that attention is removed from superficial, concrete features of the target problem. As comparison processes give rise to abstract problem schemas, members using analogical reasoning are likely to devote attention to the more generic, structural properties of the problem, and give relatively less attention to the superficial details of the problem. This helps to prevent fixation (Smith, 1995).

Interacting groups that do not use analogical reasoning are instead more likely to converge their collective attention on the superficial features of the problem. Some design studies show that individuals are prone to devoting sustained attention to the surface features of problems and solution ideas, which tends to bind their thinking to closely related knowledge domains (Jansson & Smith, 1991; Smith, 2003). Brainstorming research has revealed similar fixation effects (Nijstad & Stroebe, 2006).

If most or all members of a group succumb to this fixation effect, they may have difficulty escaping it, and this will tend to suppress divergent thinking. Research on collective information sharing has shown that groups tend to maintain attention on commonly held knowledge (Stasser & Titus, 1985), and shared perceptions of surface features represent such shared knowledge. Once this fixation effect has emerged, groups without some means of shifting the group's attention to more abstract characteristics of the problem may be limited to searching in narrowed knowledge domains closely related to the superficial, semantic characteristics of the problem.

Reducing evaluation apprehension: Analogical reasoning as routine. Another advantage of analogical reasoning for creative problem-solving groups may derive from the routine-like nature of the analogical reasoning process. This is likely to help groups avoid evaluation apprehension that is typical in brainstorming groups (Mullen et al., 1991; Paulus, Nakui, & Putman, 2006) because the routinized nature of the analogical reasoning technique reduces members' uncertainty about group processes (Gersick & Hackman, 1990). In particular, the analogical reasoning process may reduce member uncertainty about how the group will process and evaluate contributed ideas. With this reduced uncertainty about idea evaluation, group members may be less likely to believe that their own ideas will be at the mercy of other members' variable and subjective preferences. This reduction in uncertainty may lead to lowered anxiety, decreased competition, and lowered disagreement (Gersick & Hackman, 1990). Anxiety has been shown to reduce creative group idea production, through decreased member participation

(Camacho & Paulus, 1995). These effects of analogical reasoning are likely to help suppress evaluation apprehension.

An additional reduction in evaluation apprehension may be promoted by the collective attention to abstract problem schemas that group analogical reasoning promotes. In a qualitative study of cross-functional creative teams, Majchrzak, More, and Faraj (2011) found that members co-generated an abstract cognitive representation (the researchers termed this construct a "scaffold") while working together on a novel problem. The joint production of this abstract representation was accompanied by a reduction in interpersonal confrontation and heightened psychological safety, leading to smoother knowledge exchange and idea sharing. The researchers speculated that by devoting attention to the abstract representation, members were less likely to focus attention on each other, and this may have suppressed intermember tensions. This study suggests that by facilitating the development of a collective abstract problem schema, analogical reasoning may help members experience lower conflict, anxiety, and evaluation apprehension, and thereby surface and consider a greater number of ideas.

By contrast, groups that do not use analogical reasoning are especially prone to evaluation apprehension and its detrimental effects on group creativity. Brainstorming research has demonstrated that members of creative groups often fear the negative assessments of other members, and this leads to lower participation and reduced idea sharing (Mullen et al., 1991).

In sum, groups using analogical reasoning should engage in more extensive divergent thinking, avoid fixation, and experience heightened member participation and idea sharing. This provides a relative advantage over groups not using analogical reasoning, in terms of producing a higher number of rare and unusual solution ideas from a wider range of solution categories. Therefore, I hypothesize that:

H1: Interacting groups using analogical reasoning will produce creative problem solutions of higher novelty compared to interacting groups not using analogical reasoning.

H2: Interacting groups using analogical reasoning will produce creative problem solutions of higher flexibility compared to interacting groups not using analogical reasoning.

The creative advantages of analogical reasoning proposed so far deal with the divergent aspects of creative thinking that are associated with solution novelty and flexibility. Below, I argue that analogical reasoning techniques will also improve the usefulness of creative solutions because analogical reasoning techniques help members maintain a sustained focus on the underlying goals and constraints of the target problem.

Focus on problem goals and constraints. Research has shown that individuals are proficient at deriving representative abstract relational structure from analogical comparison processes involving the target problem (Catrambone & Holyoak, 1989; Gick & Holyoak, 1983). Moreover, the comparison processes involved in analogical reasoning help insure that source analogs being considered meet the goals and constraints of the target problem. Specifically, repetitive mapping and solution inference with multiple source analogs may promote usefulness because these subprocesses are relatively intellective in nature (i.e., it is often possible to demonstrate that a mapping or solution inference has been performed incorrectly (e.g., Waltz et al., 2000)), and this may help to instill and maintain an evaluative mindset in group members. Repeated cycles of mapping and inference help maintain attention on the goals and constraints of the target problem, promoting a focus on the evaluation of solutions. These evaluations may serve to identify unmet goals or constraints that can be implicitly or explicitly emphasized in a subsequent abstract problem schema, increasing the chances that future inferred solutions will meet them. In this way, analogical reasoning helps guide effective search toward more useful solutions. Analogical reasoning thus lends itself to solution evaluation and helps sustain members' attention on the goals and constraints of the target problem, something that less disciplined ideation processes or rules may avoid, omit, or even discourage (Osborn, 1953).

When analogical reasoning is not used, abstract problem schemas are less likely to develop, and members' attention may be attracted and fixed by superficial target problem features. In this case, search in long-term memory is likely to depend more upon finding similarities with semantic features and surface details of the target problem, instead of upon similarities with the problem's underlying goals and constraints. Without the repetitive subprocesses of mapping and solution inference, attention on the goals and constraints of the target problem may diminish and search may become less effective. Therefore, I hypothesize that:

> *H3: Interacting groups using analogical reasoning will produce creative problem solutions of higher usefulness compared to interacting groups not using analogical reasoning.*

Interacting groups that use analogical reasoning techniques are expected to produce creative solution ideas that are higher in novelty, flexibility, and usefulness, when compared to interacting groups that do not use analogical reasoning. Because overall creativity is a multidimensional construct comprising both solution novelty and solution usefulness, these relative advantages for interacting groups using analogical reasoning should also arise for overall creativity.

H4: Groups using analogical reasoning will produce creative problem solutions of higher overall creativity compared to groups not using analogical reasoning.

Analogical reasoning and its overall potential for group synergy

Above, I argued that groups that use analogical reasoning techniques are more likely to develop creative solutions to problems, compared to groups not using analogical reasoning techniques. In this section, I argue that analogical reasoning techniques also allow groups to realize *synergy* and to produce more creative solutions than individuals using analogical reasoning could produce in the absence of member interaction. Specifically, analogical reasoning groups whose members interact can benefit by 1) dividing the cognitive labor for analogical processing, 2) helping others avoid fixation, 3) retrieving and integrating diverse member knowledge, 4) engaging in interactive search guided by problem goals and constraints, and 5) correcting others' reasoning errors.

Enabling a division of cognitive labor. Analogical reasoning has multiple, distinct, sequential cognitive subprocesses that can be implicitly or explicitly divided among group members, depending on their talents for those processing steps. In this way, analogical reasoning lends itself to a division of cognitive labor in groups. Past research has shown that a division of cognitive labor may help groups take advantage of their cognitive resources, and in so doing, foster heightened performance (Hutchins, 1995;

Moreland, 1999; Wegner, 1987). I propose the same here for groups engaged in open-ended creative tasks.

Analogical reasoning has been described, computationally modeled, and empirically tested as a retrieve/map/infer/abstract thinking sequence (Gentner, 1983; Gick & Holyoak, 1983; Holyoak, 2012; Markman, 1997). This order of cognitive operation is fairly central to the concept – that is, one cannot map without first retrieving, nor can one infer before mapping, etc. For a creative problem-solving task, this sequence may be *repeated many times* in order to generate multiple problem solutions.

When thinking about the differences between individuals and interacting groups using an analogical reasoning strategy, these sequential and cyclical features of analogical reasoning become paramount. Individual cognitive differences interact with these structural features of analogical reasoning and affect groups and individuals differentially. Individuals vary in their abilities and preferences for remembering, comparing, recognizing similarities, and thinking abstractly, and these are some of the cognitive skills needed for carrying out the subprocesses of analogical reasoning. If an individual has a weakness or deficiency in one or more of these cognitive component steps, the entire analogical idea generation process is compromised. An individual must be proficient with *all* the steps in order to successfully use the reasoning sequence in a sustained manner. This does not mean an individual who is ineffective at one or more analogical sub-processes will not continue to generate problem solution ideas, it just means that many of the ideas they produce are probably not products of analogical reasoning.

If individuals are interacting in a group context, the subprocesses involved with analogical reasoning can be divided among members. The variety and distribution of thinking skills possessed by different members of the group make it less likely that the group will get stuck, or perform poorly, on any one subprocess in the analogical reasoning sequence. If one person is not good at a subprocess, chances are good that other members can make up for that deficiency. Dividing the cognitive labor for analogical processing may therefore help interacting groups by allowing them to engage in analogical reasoning in a sustained manner and gain the associated creative benefits, as they produce problem solutions.

Helping group members avoid fixation. When members reason together analogically, by repeatedly comparing source analogs to the target problem, they are likely to develop a common, abstract understanding of that problem. If one or more members attend to superficial features of the target problem, other members can redirect the group's attention back to the collective abstract problem schema. Repeated comparison processes that members jointly perform will tend to help correct any drifts in attention and avoid fixation, by returning their attention to the collective abstract schema. Individuals attempting to use analogical reasoning do not have this self-correcting feature provided by group interaction and collaborative comparison processes.

Supporting retrieval and integration of diverse knowledge. One creative advantage for interacting groups using analogical reasoning is suggested by research on communication modality. Markman and colleagues (2007) tested whether analogical recall was dependent on the format of presentation, contrasting written and verbal modalities. They found that source retrieval (i.e., memory recall) was enhanced when source and target analogs were presented in spoken form, compared to written form, possibly due to a reduction in working memory demands. This finding for a verbal modality effect suggests that members who interact and verbally communicate may enjoy a knowledge retrieval advantage, compared to individuals using analogical reasoning.

Groups have an advantage over individuals in terms of the diversity of knowledge available for problem-solving. The diverse source analogs that members retrieve can serve as independent source analogs on their own, or they might be combined in ways that represent new knowledge (Lewis et al., 2005; Wegner, 1987). In this way, interacting groups may be able to integrate members' diverse knowledge to produce source analogs that no individual member could come up with on their own. These integrative source analogs may possess properties and include solution approaches that are unique and qualitatively different from any of the component source analogs that went into their making (Wegner, 1987). By increasing the variety of solution approaches considered by the group, integrative source analogs are likely to generate a greater number of novel ideas, of greater solution flexibility (Guilford, 1950; Staw, 2009).

In summary, members who interact in groups are able to divide the cognitive labor for analogical reasoning, help each other avoid fixation on superficial features, realize verbal modality retrieval advantages, and retrieve and integrate diverse knowledge. Compared to groups of members who do not interact (nominal groups), interacting groups should therefore generate creative solutions of higher novelty and flexibility, when using analogical reasoning.

H5: Interacting groups using analogical reasoning will produce creative problem solutions of higher novelty compared to nominal groups using analogical reasoning.

H6: Interacting groups using analogical reasoning will produce creative problem solutions of higher flexibility compared to nominal groups using analogical reasoning.

The above arguments explain how interacting groups using analogical reasoning are more likely than nominal groups to produce problem solutions of higher novelty and flexibility. Next, I explain how analogical reasoning helps interacting groups produce problem solutions that are useful, by stimulating and guiding information search, and by helping members notice and correct faulty reasoning.

Stimulating and guiding interactive search. The greater variety of potential source analogs retrieved and compared during group interaction may help interacting groups engage in more effective search that leads to solution usefulness. As source analogs are retrieved, integrated, and compared to the target problem, the various approaches to satisfying goals and constraints are brought to the group's awareness. This may improve members' recognition of the functional and structural similarities, and differences, across source analogs, and lead to an enhanced shared understanding of the target problem at different levels of abstraction.

An enhanced shared understanding of the goals and constraints of the target problem may then lead to more effective interactive search for further potential solutions, heightening the usefulness of generated target problem solutions. As members share their perspectives on how to interpret the problem abstractly, they cue others' memories with their abstract problem interpretations. Because this intermember cueing depends on abstract problem schemas, member attention does not drift far from the underlying goals and constraints of the problem. These interactive cues may also stimulate members to reconsider previously contributed ideas that initially seemed irrelevant. These earlier ideas may garner reconsideration because their potential for meeting the goals and constraints of the problem is now recognized, in light of later abstract problem interpretations (Hargadon & Bechky, 2006). The interactive nature of this joint construction, interpretation, and sharing of abstract problem schemas is critical in realizing these usefulness benefits.

Enabling joint reasoning correction. Research in the groups as information processors paradigm has generated consistent findings showing that interacting groups tend to use information processing rules or heuristics more reliably than individuals, across a range of task types (Hinsz, Tindale, & Vollrath, 1997; Laughlin & Sweeney, 1977; Schultze, Mojzisch, & Schulz-Hardt, 2012). This research suggests that interacting groups are likely to outperform individuals at analogical reasoning. This may be explained in part by the ability of members to divide up the cognitive labor of analogical reasoning, as discussed earlier. But it may also be that interacting members can perceive when other members may be engaging in aspects of analogical reasoning incorrectly. Mapping and solution inference are not foolproof operations and can be subject to errors (Markman & Gentner, 1993, 1996). This can jeopardize the extent to which generated solutions meet the goals and constraints of a target problem, even if retrieved source analogs have the potential to do so. Interacting groups who collaborate during analogical reasoning are likely to recognize when members try to perform these steps incorrectly, enabling a corrective function that individuals do not possess, and ensuring that potential solutions are transferred properly from source to target.

Interacting groups using analogical reasoning are thus likely to develop enhanced joint abstract problem schemas that effectively stimulate and guide interactive search activities toward solutions that will meet goals and constraints of the target problem.

Interactive analogical group members also are able to detect and correct errors that fellow members may commit, helping increase the chances that retrieved knowledge will be transformed into useful solutions. This helps interacting analogical reasoning groups achieve effective search processes and capitalize on retrieved knowledge, giving them a relative solution usefulness advantage over nominal groups attempting to use analogical reasoning.

> *H7: Interacting groups using analogical reasoning will produce creative problem solutions of higher usefulness compared to nominal groups using analogical reasoning.*

Because overall creativity is a multidimensional construct comprising both solution novelty and solution usefulness, the synergistic advantages for interacting analogical groups versus nominal groups described above should extend to overall creativity.

> *H8: Interacting groups using analogical reasoning will produce creative problem solutions of higher overall creativity compared to nominal groups using analogical reasoning.*

Chapter 4: Method

I tested the hypotheses of this study with a laboratory experiment that exposed participants to different levels of group interaction and different creative problem-solving techniques. In addition to the primary experimental data for the criterion variables, survey data was also collected from each participant.

STUDY DESIGN

The study is a 2 x 4 factorial design, with "group interaction type" (interacting groups vs. nominal groups) and "problem-solving technique" (analogical reasoning, brainstorming, problem abstraction only, and analogy only) as between-groups factors. Participants were randomly assigned to either the interacting condition, in which members interacted in collaborative groups during task performance, or to the nominal condition, where members performed the task individually. Assignment to one of the problem-solving technique conditions was also randomized.

The second factor – problem-solving technique – describes the treatment condition to which participants were exposed (analogical reasoning, brainstorming, problem abstraction only, analogy only). Of the four treatments, one (brainstorming) is designed to compare against the analogical reasoning technique, and two are designed to isolate the effects of analogical reasoning and test alternative explanations. Specifically, these two conditions will allow me to test which effects are attributable to the analogical reasoning technique rather than to exposure to a problem-abstraction technique (problem abstraction only) or to analogy only. The fully-crossed design also allows for comparisons of the four techniques across interacting versus nominal groups.

I used four different readings to create the experimental manipulations. Each of the readings was designed to be comparable in terms of cognitive load (each reading required 5 minutes to complete) and different in terms of content. All written treatment materials are listed in Appendix A, and I describe them in more detail below in the section on experimental manipulations.

PARTICIPANTS

In all, 463 undergraduate students from a large public university in the southwestern United States participated in the study, to receive extra credit for a Management course. Participants were randomly assigned into 153 groups of 3 persons each. After video review and outlier analysis, three interacting groups were removed from the dataset due to excessive (> 40% of task time) talking about off-task topics. This yielded 150 total usable groups in the dataset.

The median participant age was 21 years old, and 61% of the participants were female. Participant ethnicities were distributed as follows: 47% Caucasian, 30% Asian, 18% Hispanic, 4% African American, and 1% reported multiple ethnicities. Participants had many different college majors, representing a wide cross-section of schools and colleges within the university.

A priori power analyses (univariate ANOVA) indicated that in order to provide statistical power of 0.80 for an estimated 0.35 effect size ($\hat{f}$) and a Type I error rate of α

= .05, approximately 128 total groups would be required (actual power = 0.81). For 150 groups, the detectable effect size at statistical power 0.80 and Type I error rate of 0.05 is approximately 0.32.

TASK

Participants in all conditions were asked to solve the same creative problem-solving task, which was generated for this study and pretested in a pilot study. The creative problem-solving task required participants to come up with creative solutions to a "fragile taco" problem and to propose ideas that would solve customers' problems in eating the taco. This task is well-suited to the objectives of the study for several reasons. First, it is a problem for which there is no singular, demonstrably correct solution, i.e., it is not an intellective task (Amabile, 1996; Laughlin & Ellis, 1986). This allows for the continuous generation of solution ideas without limit, except for the time allotted, which is held constant over all participants. Second, it is a problem that many people have some personal experience with, which allows all participants to feel as though they are qualified to engage in the task. This task characteristic also reduces the difficulty of solution evaluation to an acceptable level, because raters feel qualified to evaluate the ideas. Third, the task requires no special expertise or particular set of skills in order to generate solutions, which similarly facilitates member participation and ease of solution evaluation. Finally, though this task is relatively easy to address, it is not among the simplest of ideation tasks (e.g., "think of uses for a brick"), and thus it possesses enough complexity that idea building and integration are within the realm of possible collaborative outcomes.

PROCEDURE

After informed consent was obtained, participants were checked in and randomly assigned to either nominal or interacting groups in one of the four treatment conditions (analogical reasoning, brainstorming, problem abstraction only, analogy only). Interacting group members were given color name tags to wear (e.g. RED, WHITE, BLUE), and were seated at a table together. Nominal group members were seated alone, with each member seated in a separate workspace out of sight of other group members. All working spaces for groups and individuals were comparable in terms of physical and environmental characteristics (e.g., hallway noise, room temperature, table space per member, etc.). Participants were given reading materials appropriate to their randomly assigned experimental condition, and allowed 10 minutes to complete the readings. Once members completed the readings, a task instruction sheet was provided to each participant and an experimenter read the task instructions aloud, for all participants to hear.

After task instructions were read, participants were provided a large supply of Idea Sheets (e.g., the stack of Idea Sheets typically contained 50 – 100 sheets; most interacting groups and nominal group participants used between 4 and 10 sheets). Participants were then instructed to spend the next 30 minutes describing (in written form or in drawings/sketches) their solution ideas. Participants were allowed to use as many

Idea Sheets as they needed. They were also told to indicate the sources of their solution ideas at the bottom of the Idea Sheets. Interacting groups were told that they did not need to provide 3 sets of Idea Sheets with duplicated ideas, i.e., they did not need to have all members write down every idea. The Idea Sheets give evidence that they followed this instruction. Idea Sheets and video footage indicate that many groups delegated the writing activity to one member, although some groups also utilized multiple writers. All participants, regardless of experimental condition, were verbally advised to try to generate as many ideas as they could in the 30-minute time period allowed, and to make sure to describe all their ideas.

After fifteen minutes, a "halfway" notice was given by the experimenter to the participants, and when 5 minutes remained, participants were instructed to rank order what they believed were their best 3 ideas. No further guidance or criteria were given on which to judge their ideas. Idea Sheets were collected when 30 minutes had elapsed, and the post-task surveys were then given to the participants. When participants had completed the post-task surveys, they were debriefed and dismissed. The task instructions and the Idea Sheets are presented in Appendix A.

MANIPULATION MATERIALS AND CHECK

I established experimental treatment conditions by combining four different 5-minute readings in various ways. While the *content* of the readings in each condition differed, the materials are comparable in that they all describe group problem-solving techniques and all offer prescriptive advice for executing those techniques.

Participants in the **brainstorming condition** read two different blog posts about brainstorming[1]. These blog posts include tips and advice for how to run generic brainstorming meetings in real organizations, and this advice is derived from the blog authors' lay beliefs about and actual experience with brainstorming activities in their own companies. No empirical research or scholarly authority is cited in either blog post.

Participants in the **problem abstraction only condition** read one reading about problem abstraction and one of the blog posts on brainstorming[2]. This condition was meant to help isolate effects attributable to the analogical reasoning technique from those attributable to the problem abstraction technique alone, which is also theorized to facilitate creative problem-solving (Runco, 1994). The problem abstraction materials, adapted from materials used by Henderson and Trope (2009), present an example problem that illustrates the problem abstraction technique. The example problem, related to grocery bags, was presented in concrete terms, and then it was presented again in two further interpretations that stated it in successively more abstract terms. After reading the example, participants were asked to complete a similar abstraction exercise with a different creative problem. Specifically, they were asked to write two successively more abstract interpretations of a problem involving a garden hose. At the end of this reading, participants were advised to use this problem abstraction technique to help them generate problem solutions for the creative thinking task they were about to be given.

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[1] Blog posts were copied from: 1) http://designinstruct.com/articles/project-management/tips-productive-brainstorming-sessions/; and, from 2) http://www.innovationexcellence.com/blog/2012/03/23/brainstorming-fast-fun/ - sthash.9PsYwipp.dpuf/

[2] The blog posts were randomly chosen/counterbalanced such that each one was used equivalently across participants in the problem abstraction only condition. For participants in this condition (who read one of the brainstorming blog posts), the particular blog post chosen was randomly determined and counterbalanced across participants in the condition. This is true for participants in the analogy only condition as well.

Participants in the **analogy only condition** read one reading on analogical processing and one blog post on brainstorming. This condition was meant to help isolate effects attributable to analogical processing alone (i.e., without stimulating problem abstraction). The analogical processing materials were adapted from a study executed by Loewenstein, Thompson, and Gentner (1999). In these materials, a creative problem example is given, and the steps for analogical processing are described. In order to preserve some commonality between experimental conditions, one of the creative problem examples used in the problem abstraction reading materials (the grocery bag problem) was used. Following this example, the reading describes a source analog problem/solution pair, drawn from the ornithology subject matter domain, and it highlights the analogical relationship between the grocery bag problem and the ornithology example. Participants were then asked to complete an analogical mapping exercise, in which objects from the ornithology example are mapped to objects in the grocery bag problem. The exercise includes the production of an inferred solution to the grocery bag problem. At the end of this reading, participants were advised to use analogical processing to perform the creative thinking task they were about to be given.

Participants in the **analogical reasoning condition** read one reading about analogical processing and one reading about problem abstraction. Together, these readings describe the problem-solving technique of analogical reasoning, which has as a theorized by-product, problem abstraction (Gick & Holyoak, 1983). I elected to stimulate problem abstraction in this condition rather than to let it emerge naturally because there is some evidence suggesting that individuals may be more apt to develop and utilize abstract problem schema during analogical reasoning when given cues meant to stimulate abstract thinking (Beveridge & Parkins, 1987; Gick & Holyoak, 1983; Holyoak, 2012; Linsey, Laux, Clauss, Wood, & Markman, 2007). All the reading materials used in the study are presented in Appendix A.

Manipulation check. In a post-task survey, members responded to a single item that was posed as a multiple choice question, asking them what they had read before the task. Consistent with the manipulations, I found significant differences between member responses in the 4 different problem-solving technique conditions (analogical reasoning, brainstorming, problem abstraction alone, analogy alone). A chi-square test of independence was performed on the relationship between experimental condition and the nominal response to the survey item. The chi-square was statistically significant $\chi^2(9, N = 457) = 1287, p < .001$, indicating that the frequency with which participants chose the different item responses corresponded well to experimental condition. Results of this test are shown in Table 1.

MEASURES

Dependent Variables

Consistent with past work on creativity (Amabile, 1996; Zhou & Shalley, 2003), group creativity is defined here as the novelty and usefulness of a group's output. I used four measures to assess the solution ideas generated by participants: novelty, flexibility, usefulness, and overall creativity.

Solution ideas were taken from the Idea Sheets and transcribed into electronic files for subsequent rating. Due to the great number of ideas (over 3,600 ideas were generated by participants in this study), the ratings were performed in a multi-step procedure, similar to past creativity studies that evaluated large numbers of outputs (for an example, see Rietzschel, Nijstad, & Stroebe, 2006). The procedure involved first calibrating the raters to each other to establish interrater similarity ("pre-ratings calibration"), then distributing different sets of ideas among raters for assessment, and then checking interrater similarity again with a post-ratings calibration. Thus, there are two sets of interrater agreement and reliability estimates: one set for the pre-ratings calibration, and one for the post-ratings calibration. The full details of this rater calibration procedure are presented in Appendix B.

Nominal groups were composed randomly. For each nominal group, ideas from the three individuals' Idea Sheets were combined. Ideas were rated and marked for redundancy (i.e., some ideas were generated by more than one member of a nominal group), and redundant ideas were not included in the group level averages computed for all the dependent variables described below. This is consistent with past studies that have used randomly composed nominal groups for comparisons with interacting groups (e.g., Taylor et al., 1958). Next, I describe how the dependent variables were operationalized, and then I include information on inter-rater agreement (IRA) and inter-rater reliability (IRR).

Novelty. Solution ideas were judged for novelty by three raters, blind to hypotheses and experimental conditions. I met together with all the raters and we reviewed selected text passages taken from Amabile (Amabile, 1996) that helped establish the definition of novelty[3]. Afterwards, the raters independently evaluated the novelty of solution ideas using a 7 point Likert-type scale ranging from 1 (*not novel at all*) to 7 (*extremely novel*). A group-level novelty variable was computed as the average of novelty ratings of all the ideas generated by the group.

Usefulness. Solution ideas were judged for usefulness by three raters, blind to hypotheses and experimental conditions. They independently rated the usefulness of solution ideas using a 7 point Likert-type scale ranging from 1 (*not useful at all*) to 7 (*extremely useful*). A group-level usefulness variable for each group was calculated by averaging the usefulness ratings of all the ideas generated by the group.

Flexibility. Flexibility was scored for each group using flexibility scoring methods similar to past ideation studies (Baruah & Paulus, 2008; Goncalo & Staw, 2006; Kohn & Smith, 2010; Nijstad et al., 2002, 2003) in which flexibility is measured as a function of the number of categories of ideas generated. Two undergraduate raters, blind to this study's hypotheses, looked through approximately half of all solution ideas and generated two lists of independent problem solution category dimensions: solution means and solution goals (to review an earlier example of this methodology, see Nijstad et al., 2002). For example, a goal of many of the problem solutions was to prevent the taco shell from breaking; a common means that many solutions implemented was to add an extra taco shell. After two rounds of collaborative meetings, the raters and I came up with a list

[3] We did the same for usefulness and overall creativity during the meeting. The excerpts we used are shown in Appendix B in the section on rater calibration procedures.

of 24 means and 8 goals, which covered the ideas we had looked through. Tables 2 and 3 list the goals and means.

Using this approach, an idea category is a combination of a solution means and a solution goal (Nijstad et al., 2002). For 24 solution means and 8 solution goals, there are 192 unique idea categories that can be generated. Four undergraduate raters then were each randomly assigned about a quarter of the ideas in the dataset, and they categorized them. I calculated flexibility for each group by taking the number of non-redundant categories represented by the ideas the group generated, and dividing by the total number of ideas generated by the group. The flexibility measure represents the average number of non-redundant categories contributed per idea generated (Goncalo & Staw, 2006).

Overall group creativity. Three raters independently judged the overall creativity of solution ideas with a 7 point Likert-type scale ranging from 1 (*not creative at all*) to 7 (*extremely creative*). Overall creativity for each group was calculated by averaging the overall creativity ratings of all the ideas generated by that group.

Interrater reliability and agreement

Interrater reliability (IRR) and agreement (IRA) were assessed using r_{wg} and ICC indices for novelty, usefulness, and overall creativity. The full description of the pre-ratings and post-ratings calibration process is described in Appendix B. Next, I give the results for the IRR and IRA analyses for the dependent variables.

Group idea novelty. Three undergraduate raters independently rated ideas for novelty. Using a rectangular uniform null distribution as the comparison variance condition, the mean and median values for r_{wg} were 0.81 and 0.92, respectively, for the raters' novelty ratings of ideas in the pre-ratings calibration dataset. These IRA parameter values indicate that the raters were in strong agreement, according to guidance by LeBreton and Senter (2008). With ideas treated as the random effect and raters treated as the fixed effect, the ICC(A,1) value for the pre-ratings calibration dataset novelty ratings was 0.75, which reflects good interrater agreement and reliability.

Again using a rectangular uniform null distribution as the comparison variance condition, the mean and median values for r_{wg} were 0.76 and 0.75, respectively, for the raters' ratings of the 50 ideas in the post-ratings calibration dataset. These IRA parameter values indicate that the raters were still in reasonably good agreement on the novelty ratings. The ICC(A,1) was 0.70, which reflects acceptable interrater agreement and reliability. The test-retest reliabilities between the pre-ratings and post-ratings came out to 0.93, 0.92, and 0.94 for each raters' novelty ratings.

Usefulness. Three undergraduate raters independently rated ideas for usefulness. Using a rectangular uniform null distribution as the comparison variance condition, the mean and median values for r_{wg} were 0.82 and 0.92, respectively, for the pre-ratings calibration dataset. These IRA parameter values indicate strong agreement on the usefulness ratings. With ideas treated as the random effect and raters treated as the fixed effect, the ICC(A,1) value for the pre-ratings calibration dataset usefulness ratings was 0.64, which reflects acceptable interrater agreement and reliability.

For the post-ratings calibration dataset, the mean and median values for r_{wg} were 0.75 and 0.75, respectively. These IRA parameter values indicate that the raters were still in good agreement on the usefulness ratings. The ICC(A,1) was 0.64, and this reflects acceptable interrater agreement and reliability. The test-retest reliability values came out to 0.91, 0.94, and 0.83 for each raters' usefulness scores.

Overall group creativity. Three undergraduate raters independently rated ideas for overall creativity. Using a rectangular uniform null distribution as the comparison variance condition, the mean and median values for r_{wg} were 0.88 and 0.92, respectively, for the pre-ratings calibration dataset. These IRA parameter values indicate strong agreement on the overall creativity ratings. With ideas treated as the random effect and raters treated as the fixed effect, the ICC(A,1) value was 0.53, which reflects nominally acceptable interrater agreement and reliability.

For the post-ratings calibration dataset, the mean and median values for r_{wg} were 0.75 and 0.75, respectively. These IRA parameter values indicate that the raters were still in good agreement on the overall creativity ratings. The ICC(A,1) was 0.40, which indicates marginal interrater agreement and reliability. The test-retest reliability values came out to 0.92, 0.81, and 0.91 for each raters' overall creativity scores.

Group Idea flexibility. Interrater agreement for the pre-ratings categorizations was assessed with a generalized version of Cohen's kappa which is suited to more than two raters (Cohen, 1960; Fleiss, 1971)[4]. The generalized kappa parameter was 0.53 ($p < .001$), 95% CI (0.51, 0.54) for the pre-ratings categorization calibration dataset, and this indicates moderate agreement between raters (Landis & Koch, 1977).

[4] See https://www.ibm.com/developerworks/community/files/app/folder/bbe88aaf-f3cd-466a-83fb-592d48eecb1c for a list of IBM developer software tools for SPSS, including the Fleiss kappa module used in this study.

The generalized kappa parameter was 0.58 ($p < .001$), 95% CI (0.56, 0.60) for the post-ratings categorization calibration dataset, and this again indicates moderate agreement between raters (Landis & Koch, 1977).

CONTROL VARIABLES

Prior research indicates there may be some meaningful relationships between creativity and certain characteristics of individuals and groups. In order to account for alternative explanations for group creativity, I include the following control variables, and I cite relevant research in each section that provides evidence that they might be important for this study.

Personality. Theory and empirical findings suggest personality may be important for individual and group creativity (e.g., Amabile, 1996; Baer et al., 2008). Survey items for personality, taken from the short 10-item scale developed by Gosling, Rentfrow, and Swann Jr (2003) were administered. The scale includes 2 items for each of the Big Five personality dimensions. Cronbach's alpha [Pearson r] for each of the 5 dimensions were: Extraversion: 0.82 [0.70]; Agreeableness: 0.45 [0.30]; Conscientiousness: 0.51 [0.36]; Emotional Stability: 0.67 [0.51]; and Openness to Experience: 0.48 [0.33]. All participants, regardless of experimental treatment condition, completed these items.

Transactive memory systems. Recently, some researchers have theorized and found evidence of an association between TMS and group creativity (e.g., Gino et al., 2010; Gino, Todorova, Miron-Spektor, & Argote, 2009). I measured TMS in interacting groups to account for this potential association, using the 15-item multidimensional TMS scale developed by Lewis (2003), with some minor wording changes and using a 7 point Likert-type scale. To assess internal consistency, I used the 15 items at the individual level, and I also averaged responses across members for each item to generate group item averages. Cronbach's alpha for the individual-level scale was 0.78, and for group item averages it was 0.82.

I averaged responses across the 15 items to form a TMS composite score for each group member. Because the TMS measure is intended to represent a group level construct, I evaluated the statistical appropriateness of aggregating the composite scores to the group level using $r_{wg(j)}$ indices for interrater agreement. The mean [median] $r_{wg(j)}$ value was 0.94 [0.95], indicating very strong agreement among members of each group. TMS at the group level was calculated as the unweighted average of the 3 composite scores within each group.

Cohesion. Some have theorized that group cohesion will facilitate the serious exchange of diverse perspectives and ideas (Van Der Zee & Paulus, 2008), which may help creative groups. Members of interacting groups completed a 4-item measure of group cohesion adapted from Seashore (1954). Cronbach's alpha for the individual level scale was 0.80, and for group item averages it was 0.84. For composite scores averaged across each member's responses to the 4 items, the mean [median] $r_{wg(j)}$ value was 0.93 [0.96], indicating very strong agreement among members. Group cohesion was calculated as the average of the 3 composite scores within each group.

Individualism/Collectivism. Theory and empirical findings suggest that individualistic and collectivistic values can have differential effects on creativity

(Goncalo & Staw, 2006). To account for this potential alternative explanation, individualism/collectivism was measured for all participants in the study, using 3 items from Wagner (1995), with higher scores indicating higher levels of individualism. Cronbach's alpha for the individual level scale was 0.76. For composite scores averaged across each member's responses to the 3 items, the mean [median] $r_{wg(j)}$ value was 0.55 [0.63]. These IRA parameter values indicate moderate agreement. Group level individualism/collectivism was calculated as the average of the 3 composite scores within each group in the interacting condition.

Psychological Safety. Studies of group learning and performance indicate that when members share a belief that the group is safe for risk-taking, they are more willing to seek and exchange information (Edmondson, 1999). In a group creative context, psychological safety may be relevant to helping members overcome a fear of negative evaluation, one of the theorized mechanisms of production loss in creative groups (Paulus & Dzindolet, 1993; Paulus et al., 2006). Psychological safety was measured in interacting groups to assess potential effects, using a 3-item scale adapted for this laboratory task from Edmondson's (1999) field measure.

Cronbach's alpha for the individual level scale was 0.60, and for group item averages it was 0.65. For composite scores averaged across each member's responses to the 3 items, the mean [median] $r_{wg(j)}$ value was 0.89 [0.94]. These IRA parameter values indicate very strong agreement. Group psychological safety was calculated as the average of the 3 composite scores within each group.

Task conflict. Task conflict has been theorized as an important collective process that affects the extent to which group members exchange potentially diverse and valuable information (Jehn, 1995; Jehn, Northcraft, & Neale, 1999), but whether the effects are functional is a topic of debate in the literature, and one that requires a closer examination of task and contextual factors (De Dreu & Weingart, 2003; de Wit, Greer, & Jehn, 2012). Due to the potential for task conflict to affect group interaction during creative collaboration, interacting group members completed a 3-item measure of task conflict under development by Weingart (2011).

Cronbach's alpha for the individual level scale was 0.81, and for group item averages it was 0.88. For composite scores averaged across each member's responses to the 3 items, the mean [median] $r_{wg(j)}$ value was 0.65 [0.81], indicating moderate to strong agreement. Group task conflict was calculated as the average of the 3 composite scores within each group.

Positive and negative affect. Positive affect has been linked to creativity in the literature, and it has been theorized to improve individuals' abilities to think divergently and come up with new ideas (Amabile, Barsade, Mueller, & Staw, 2005; Isen, Daubman, & Nowicki, 1987). However, some other studies have found that negative affect improves creativity under certain conditions (George & Zhou, 2002, 2007). Similar to the latter 2 studies, positive and negative affect were measured with the Positive and Negative Affect Scale (PANAS) (Watson, Clark, & Tellegen, 1988), which uses 10 items each for positive and negative affect. All participants, whether assigned to interacting or nominal conditions, completed the PANAS items. For internal consistency, Cronbach's alpha was 0.89 for the positive affect scale, and it was 0.75 for the negative affect scale.

Affect is, according to past theorizing and empirical work (Barsade & Gibson, 1998; Bartel & Saavedra, 2000), "sufficiently collective to merit consideration as a group level construct" (Kelly & Barsade, 2001). For composite scores averaged across each interacting group member's responses to the 10 positive affect items, the mean [median] $r_{wg(j)}$ value was 0.96 [0.97]. The corresponding IRA estimate for the negative affect composite scores was 0.99 [1.00]. These IRA parameter values indicate very strong agreement. Group level positive and negative affect were calculated as the average of the 3 corresponding composite scores within each group.

Demographic variables. Additional variables including age, gender, school major, work experience, native language, and familiarity with other members (for interacting groups) were collected in a post-task survey. All participants completed these items, regardless of experimental treatment condition, to examine potential associations with the criterion variables. Diversity of gender, ethnicity, and native language was calculated using Blau's index (Blau, 1977).

All the post-task survey items are listed in Appendix C.

Chapter 5: Results

Survey Data and Correlations

This study is an experiment, but post-task survey data were also collected along with the dependent variables and video data. The survey data differ based on the interacting/nominal status of the groups. Some of the interacting groups' survey questions asked about group interaction (e.g., cohesion, TMS, etc.), and these questions could not be given to the nominal group members, because they did not experience any group interaction. Thus, the sample size for some data collected from interacting groups is N=88. The means, standard deviations, alpha reliabilities, and correlations for the entire dataset are shown in Table 4 (sample sizes are noted in the table).

Notable correlations

Some of the control variables are significantly correlated with one or more of the dependent variables: novelty, flexibility, usefulness, and overall creativity. Individualism is positively associated with novelty and negatively associated with flexibility. Recall that the flexibility variable is operationalized as the number of solution categories generated divided by the total number of ideas. Thus, flexibility is low if the number of ideas is large relative to the number of categories generated. A negative correlation between flexibility and individualism could therefore result if individualism were positively related to the number of ideas generated[5].

Group averages for some personality variables are significantly associated with creative outcomes. Group average agreeableness is negatively associated with novelty, although the effect is small. The group average for openness to experience, which has been theorized to promote flexible thinking (Amabile, 1996) is negatively associated with

[5] Individualism and number of ideas produced (fluency) are correlated 0.22^{**}, $p < .01$.

both overall creativity and solution novelty, although again, these effects are small. These results should be interpreted with caution, however, because the reliabilities of these two personality variables in this study are below the commonly-accepted cutoff of $\alpha = 0.70$. The group average for extraversion is positively associated with usefulness, and group emotional stability is positively associated with flexibility.

There is a positive overall association between task conflict and solution usefulness. This may indicate that interacting groups who experienced task conflict used these debates in a functional way to assess potential solution ideas as to their usefulness or feasibility.

The relationships between the criterion variables for the entire dataset are also of interest. Overall creativity is positively associated with both novelty and usefulness, which aligns with the conceptual definition of overall creativity as a multidimensional construct reflecting both novelty and usefulness. Novelty and usefulness exhibit no significant association with each other, and this is consistent with some other studies that have measured both dimensions (Amabile, 1983, 1996; Montag et al., 2012).

Based on these data and on past theorizing about the effects of some of these variables on creativity, I performed supplemental tests of hypotheses (described later), controlling for individualism, the personality variables, and task conflict.

CELL MEANS AND OVERALL PATTERN OF RESULTS

Tables 5, 6, 7, and 8 show the dependent variable cell means and standard deviations for novelty, flexibility, usefulness, and overall creativity, respectively. I analyzed the overall pattern of results for each dependent variable using one-way ANOVA and post-hoc pairwise comparisons. The single between-groups factor was a general experimental condition factor; it distinguished between each of the eight test cell conditions. To preserve statistical power, I used the Fisher's LSD pairwise procedure to report the significant differences between means in the overall pattern of results, even though this procedure is somewhat liberal in protecting the overall Type I error rate (Stevens, 2007). The analyses were focused on two main sets of comparisons. The first comparison set involved looking at differences between interacting and nominal groups in each problem-solving condition. The second set of comparisons involved looking exclusively at interacting groups to better understand the relative differences in effects of analogical reasoning, analogy only, and problem abstraction only. In addition to analyzing the dependent variables this way, I also analyzed fluency (group idea production) using the same procedures. I describe the results next.

Overall pattern: Solution novelty

Figure 1 shows the solution novelty group means across the eight experimental conditions. The pattern of results shows that the analogical reasoning condition was the only problem-solving condition in which interacting groups seemed to outperform nominal groups on solution novelty. The one-way ANOVA using novelty as the dependent variable and experimental condition as between-groups factor was significant, $F(7, 142) = 4.67$, $p < .001$, $\eta^2 = 0.19$. Post-hoc pairwise comparisons using the LSD procedure revealed that interacting groups using analogical reasoning produced solutions of significantly higher novelty compared to nominal groups using analogical reasoning ($\Delta M = 0.39$, 95% CI [0.08, 0.70], $p < .05$). Conversely, interacting groups using analogy only produced solutions of significantly lower novelty compared to nominal groups using analogy only ($\Delta M = 0.44$, 95% CI [0.14, 0.75], $p < .01$). The pattern of results for the brainstorming and problem abstraction only conditions was similar to that of the analogy only condition, i.e., nominal groups appeared to outperform interacting groups, but the pairwise comparisons did not reach statistical significance ($\Delta M = 0.27$, 95% CI [-0.07, 0.60], $p = .12$, ns; and $\Delta M = 0.16$, 95% CI [-0.18, 0.50], $p = .36$, ns, respectively).

Interacting groups comparisons: Solution novelty

Post-hoc pairwise comparisons using the LSD procedure revealed a significant difference between interacting groups that used analogical reasoning and interacting groups that used analogy only. Interacting groups using analogical reasoning produced solutions of higher novelty compared to interacting groups using analogy only ($\Delta M = 0.77$, 95% CI [0.48, 1.06], $p < .01$). Also, interacting groups using analogical reasoning produced solutions of higher novelty compared to interacting groups using problem abstraction only ($\Delta M = 0.32$, 95% CI [0.02, 0.61], $p < .05$), and also compared to interacting groups using brainstorming ($\Delta M = 0.35$, 95% CI [0.06, 0.64], $p < .05$).

Inspection of the overall pattern also suggests that interacting groups in the analogy only condition may have performed significantly worse on solution novelty compared to interacting groups in the brainstorming and in the problem abstraction only conditions. This was true. Interacting groups in the analogy only condition produced solutions of lower novelty compared to interacting groups in both the brainstorming and the problem abstraction only conditions ($\Delta M = 0.42$, 95% CI [0.13, 0.71], $p < .01$; and $\Delta M = 0.45$, 95% CI [0.16, 0.75], $p < .01$, respectively). In short, interacting groups in the analogy only condition produced significantly less novel solutions compared to interacting groups in any of the other problem-solving conditions.

Overall pattern: Solution flexibility

Figure 2 shows the solution flexibility group means across the eight experimental conditions. The overall pattern of results shows that for flexibility, interacting groups seemed to have an advantage over nominal groups, and this advantage held across all four problem-solving conditions. The one-way ANOVA using flexibility as the dependent variable and experimental condition as between-groups factor was significant, $F(7, 142) = 5.61$, $p < .001$, $\eta^2 = 0.22$. Post-hoc pairwise comparisons using the LSD procedure revealed that interacting groups using analogical reasoning produced solutions of significantly higher flexibility compared to nominal groups using analogical reasoning ($\Delta M = 0.10$, 95% CI [0.03, 0.18], $p < .01$). Similarly, interacting groups produced solutions of higher flexibility compared to nominal groups for both the brainstorming and the problem abstraction only conditions ($\Delta M = 0.13$, 95% CI [0.05, 0.21], $p < .01$; and $\Delta M = 0.14$, 95% CI [0.06, 0.22], $p < .01$, respectively). Conversely, no significant flexibility difference was found between solutions produced by interacting groups using analogy only and nominal groups using analogy only ($\Delta M = 0.06$, 95% CI [-0.01, 0.13], $p = .10$, ns).

Interacting groups comparisons: Solution flexibility

An LSD post-hoc test revealed no significant flexibility difference between interacting groups that used analogical reasoning and interacting groups that used analogy only, ($\Delta M = 0.05$, 95% CI [-0.02, 0.12], $p = .17$, ns). Similarly, there were no significant solution flexibility differences between interacting groups using analogical reasoning and interacting groups using problem abstraction only ($\Delta M = 0.03$, 95% CI [-0.04, 0.10], $p = .34$, ns), nor between interacting groups using analogical reasoning and interacting groups using brainstorming ($\Delta M = 0.06$, 95% CI [-0.01, 0.13], $p = .08$, ns).

Overall pattern: Solution usefulness

Figure 3 shows the solution usefulness group means across the eight experimental conditions. Like the novelty results, the pattern of usefulness results shows that the analogical reasoning condition was the only problem-solving condition in which interacting groups seemed to outperform nominal groups. The one-way ANOVA using usefulness as the dependent variable and experimental condition as between-groups factor was significant, $F(7, 142) = 17.65$, $p < .001$, $\eta^2 = 0.47$. Post-hoc pairwise comparisons using the LSD procedure revealed that interacting groups using analogical reasoning produced solutions of significantly higher usefulness compared to nominal groups using analogical reasoning ($\Delta M = 1.13$, 95% CI [0.86, 1.41], $p < .001$). Conversely, interacting groups using analogy only produced solutions of lower usefulness compared to nominal groups using analogy only ($\Delta M = 0.31$, 95% CI [0.04, 0.59], $p < .05$). The pattern of usefulness results for the brainstorming and problem abstraction only conditions was similar to that of the analogy only condition, but the pairwise comparisons did not reach statistical significance ($\Delta M = 0.26$, 95% CI [-0.04, 0.56], $p = .09$, ns; and $\Delta M = 0.03$, 95% CI [-0.27, 0.33], $p = .84$, ns, respectively).

Interacting groups comparisons: Solution usefulness

Post-hoc pairwise comparisons using the LSD procedure revealed a significant difference between interacting groups that used analogical reasoning and interacting groups that used analogy only. Interacting groups using analogical reasoning produced solutions of higher usefulness compared to interacting groups using analogy only, ($\Delta M = 1.25$, 95% CI [0.99, 1.51], $p < .001$). The LSD post-hoc procedure also revealed significant differences between interacting groups that used analogical reasoning and interacting groups that used either brainstorming or problem abstraction only. Interacting groups using analogical reasoning produced solutions of higher usefulness compared to interacting groups using problem abstraction only, ($\Delta M = 1.07$, 95% CI [0.81, 1.32], $p < .001$), and they also produced solutions of higher usefulness compared to interacting groups using brainstorming ($\Delta M = 1.11$, 95% CI [0.85, 1.37], $p < .001$).

Overall pattern: Solution overall creativity

Figure 4 shows the solution overall creativity group means across the eight experimental conditions. The pattern of overall creativity results shows that the analogical reasoning condition was the only problem-solving condition in which interacting groups appeared to significantly outperform nominal groups. The data also suggest that nominal groups may have outperformed interacting groups in the brainstorming and problem abstraction only conditions, which is the reverse pattern compared to the analogical reasoning groups. The one-way ANOVA using overall creativity as the dependent variable and experimental condition as between-groups factor was significant, $F(7, 142) = 3.64$, $p < .001$, $\eta^2 = 0.15$. Post-hoc pairwise comparisons using the LSD procedure revealed a significant overall creativity difference between interacting groups that used analogical reasoning and nominal groups that used analogical reasoning ($\Delta M = 0.33$, 95% CI [0.13, 0.52], $p < .01$). Conversely, interacting groups using brainstorming produced solutions of lower overall creativity compared to nominal groups using brainstorming ($\Delta M = 0.32$, 95% CI [0.11, 0.54], $p < .01$). Also, interacting groups using problem abstraction only produced solutions of lower overall creativity compared to nominal groups using problem abstraction only ($\Delta M = 0.22$, 95% CI [0.005, 0.44], $p < .05$). No significant overall creativity difference was found between solutions produced by interacting groups using analogy only and nominal groups using analogy only ($\Delta M = 0.02$, 95% CI [-0.18, 0.22], $p = .84$, ns).

Interacting groups comparisons: Solution overall creativity

Post-hoc pairwise comparisons using the LSD procedure revealed a significant solution creativity difference between interacting groups that used analogical reasoning and interacting groups that used analogy only. Interacting groups using analogical reasoning produced solutions of higher overall creativity compared to interacting groups using analogy only, ($\Delta M = 0.22$, 95% CI [0.03, 0.40], $p < .05$). The LSD post-hoc procedure also revealed that interacting groups using analogical reasoning produced solutions of higher overall creativity compared to interacting groups using problem abstraction only, ($\Delta M = 0.31$, 95% CI [0.13, 0.50], $p < .01$), and they also produced solutions of higher overall creativity compared to interacting groups using brainstorming ($\Delta M = 0.30$, 95% CI [0.11, 0.48], $p < .01$).

Overall pattern: Fluency

Figure 5 shows the fluency group means across the eight experimental conditions. The overall pattern of results shows that for fluency, nominal groups seemed to have an advantage over interacting groups consistently across the four problem-solving conditions. The one-way ANOVA using fluency as the dependent variable and experimental condition as between-groups factor was significant, $F(7, 142) = 7.87$, $p < .001$, $\eta^2 = 0.28$. Post-hoc pairwise comparisons using the LSD procedure revealed a significant fluency difference between interacting groups that used analogical reasoning and nominal groups that used analogical reasoning, with nominal groups outperforming interacting groups ($\Delta M = 7.96$, 95% CI [1.84, 14.08], $p < .05$). Similarly, interacting groups produced fewer solutions compared to nominal groups for both the brainstorming and the problem abstraction only conditions ($\Delta M = 10.14$, 95% CI [3.41, 16.88], $p < .01$; and $\Delta M = 13.49$, 95% CI [6.75, 20.22], $p < .01$, respectively). Conversely, no significant fluency difference was found between solutions produced by interacting groups using analogy only and nominal groups using analogy only ($\Delta M = 4.19$, 95% CI [-1.93, 10.31], $p = .18$, ns).

Interacting groups comparisons: Fluency

Post-hoc pairwise comparisons using the LSD procedure revealed a significant fluency difference between interacting groups that used analogical reasoning and interacting groups that used analogy only. Interacting groups using analogical reasoning produced fewer solutions compared to interacting groups using analogy only, (ΔM = 6.55, 95% CI [0.74, 12.35], $p < .05$). The LSD post-hoc procedure also revealed that interacting groups using analogical reasoning produced fewer solutions compared to interacting groups using problem abstraction only, (ΔM = 6.77, 95% CI [0.97, 12.58], $p < .05$), and they also produced fewer solutions compared to interacting groups using brainstorming (ΔM = 9.50, 95% CI [3.69, 15,31], $p < .01$). In fact, interacting groups using analogical reasoning produced fewer ideas than any of the seven other experimental conditions in the study[6].

TESTS OF HYPOTHESES

Hypotheses were tested using analysis of variance and planned comparisons. The first four hypotheses were tests between interacting groups using analogical reasoning and groups not using analogical reasoning. As stated in Chapter 4, groups not using analogical reasoning were exposed to blog posts describing brainstorming as an idea-generating technique, and these are the groups against which analogical reasoning groups were compared. Hypotheses 5-8 tested for group synergy by comparing interacting and nominal groups using analogical reasoning.

The study was designed and executed as a 2 x 4 factorial design[7], with "group interaction type" (interacting groups vs. nominal groups) and "problem-solving type"

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[6] LSD analyses showed this to be true; this finding can also be deduced from the results given here.

[7] I used the Type III sum of squares method in SPSS for all ANOVA analyses, to address correlated effects issues related to unequal cell sizes for factorial designs (Stevens, 2007: 142).

(brainstorming, problem abstraction only, analogy only, analogical reasoning) as between-groups factors. Results of the hypotheses tests without control variables are presented in the next section, and they are followed by subsequent analyses incorporating control variables.

Tests between interacting groups

Hypothesis 1 predicted that interacting groups using analogical reasoning would produce creative problem solutions of higher novelty compared to interacting groups not using analogical reasoning. A 2 x 4 factorial ANOVA using novelty as the dependent variable and between-group factors for group interaction and problem-solving technique was significant, $F(7, 142) = 4.67$, $p < .001$, $\eta^2 = 0.19$. A planned contrast assessing the novelty difference between interacting groups that used analogical reasoning and interacting groups that did not use analogical reasoning (i.e., that used brainstorming) was significant. Interacting groups using analogical reasoning produced solutions of higher novelty compared to interacting groups that did not use analogical reasoning, ($M = 4.51$, $SD = 0.40$ vs. $M = 4.16$, $SD = 0.34$, $t[142] = 2.36$, $p < .05$). These results lend support to Hypothesis 1.

Hypothesis 2 predicted that interacting groups using analogical reasoning would produce creative problem solutions of higher flexibility compared to interacting groups not using analogical reasoning. A 2 x 4 factorial ANOVA with flexibility as the dependent variable and between-group factors for group interaction and problem-solving technique was significant, $F(7, 142) = 5.61$, $p < .001$, $\eta^2 = 0.22$. A planned contrast assessing the difference in flexibility between interacting groups using analogical reasoning and those that did not use analogical reasoning revealed no significant difference. Interacting groups using analogical reasoning produced solutions of marginally higher flexibility compared to interacting groups using brainstorming, (M = 0.74, SD = 0.12 vs. M = 0.68, SD = 0.08, t[142] = 1.74, p = .084, ns)[8]. Thus, Hypothesis 2 was not supported.

Hypothesis 3 predicted that interacting analogical reasoning groups would produce creative problem solutions of higher usefulness compared to interacting groups not using analogical reasoning. A 2 x 4 factorial ANOVA with usefulness as the dependent variable and between-group factors for group interaction and problem-solving technique was significant, F(7, 142) = 17.65, p < .001, η^2= 0.47. A planned contrast assessing the difference between interacting groups that used analogical reasoning and those that did not use analogical reasoning revealed a significant difference. Interacting groups using analogical reasoning produced solutions of higher usefulness compared to interacting groups that did not use analogical reasoning, (M = 5.18, SD = 0.40 vs. M = 4.07, SD = 0.34, t[142] = 8.49, p < .001). These results support Hypothesis 3.

Hypothesis 4 predicted that interacting groups using analogical reasoning would produce ideas higher in overall creativity compared to interacting groups not using analogical reasoning. A 2 x 4 factorial ANOVA using the measure for overall creativity as the dependent variable and between-group factors for group interaction and problem-solving technique was significant, F(7, 142) = 3.64, p < .001, η^2= 0.15. A planned contrast assessing the difference in overall creativity between interacting groups that used analogical reasoning and interacting groups that did not revealed a significant difference. Interacting groups using analogical reasoning produced solutions of higher overall creativity compared to interacting groups that did not use analogical reasoning, (M =

[8] The flexibility data rendered a significant Levene's test for homogeneity of variances, indicating population variances may have been heterogeneous. Conversely, a Hartley's Fmax test indicated no problem with the homogeneity of variance assumption. With Welch's adjustment for heterogeneous variances, the Hypothesis 2 planned contrast t statistic was t[36.215] = 1.96, p = .058.

3.83, SD = 0.36 vs. M = 3.54, SD = 0.17, t[142] = 3.14, $p < .01$)[9]. These results support Hypothesis 4.

Tests between interacting groups and nominal groups

Hypotheses 5-8 examine the extent to which group interaction produces synergies with respect to novelty, flexibility, usefulness, and overall creativity. Hypothesis 5 predicted that interacting groups using analogical reasoning would produce ideas higher in novelty compared to nominal groups using analogical reasoning. The 2 x 4 factorial ANOVA using the measure for novelty as the dependent variable and between-group factors for group interaction and problem-solving technique was significant, $F(7, 142) = 4.67$, $p < .001$, $\eta^2 = 0.19$. A planned contrast assessing the novelty difference between interacting and nominal groups that used analogical reasoning revealed a significant difference. Interacting groups using analogical reasoning produced solutions of higher novelty compared to nominal groups using analogical reasoning, (M = 4.51, SD = 0.40 vs. M = 4.12, SD = 0.56, t[142] = 2.51, $p < .05$). These results lend support to Hypothesis 5 and indicate that group interaction produces synergistic effects for analogical reasoning on solution novelty.

Hypothesis 6 predicted interacting groups that used analogical reasoning would produce ideas higher in flexibility compared to nominal analogical groups. The 2 x 4 factorial ANOVA using the measure for flexibility as the dependent variable and between-group factors for group interaction and problem-solving technique was significant, $F(7, 142) = 5.61$, $p < .001$, $\eta^2 = 0.22$. A planned contrast assessing the difference in flexibility between interacting and nominal groups using analogical

[9] The overall creativity data rendered a significant Levene's test for homogeneity of variances, and a value for Hartley's Fmax that exceeded the critical value, indicating population variances may have been heterogeneous. With Welch's adjustment for heterogeneous variances, the t statistic was t[29.98] = 3.49, p = .002.

reasoning revealed a significant effect. Solution flexibility was higher for groups using analogical reasoning in the interacting condition than for groups using analogical reasoning in the nominal group condition (M = 0.74, SD = 0.12 vs. M = 0.63, SD = 0.13, t[142] = 2.85, $p < .05$)[10]. Hypothesis 6 is therefore supported, suggesting that group interaction produces synergistic effects for analogical reasoning on solution flexibility.

Hypothesis 7 predicted that interacting groups using analogical reasoning would produce creative problem solutions of higher usefulness compared to nominal groups using analogical reasoning. The 2 x 4 factorial ANOVA using the measure for usefulness as the dependent variable and between-group factors for group interaction and problem-solving technique was significant, $F(7, 142) = 17.65$, $p < .001$, $\eta^2 = 0.47$. A planned contrast assessing the solution usefulness difference between interacting and nominal groups that used analogical reasoning revealed a significant difference. Interacting groups using analogical reasoning produced solutions of higher usefulness compared to nominal groups using analogical reasoning, (M = 5.18, SD = 0.40 vs. M = 4.05, SD = 0.61, t[142] = 8.20, $p < .001$). These results support Hypothesis 7 and suggest that group interaction produces synergistic effects for analogical reasoning on solution usefulness.

Hypothesis 8 predicted that interacting groups using analogical reasoning would produce ideas higher in overall creativity compared to nominal groups using analogical reasoning. The 2 x 4 factorial ANOVA using the measure for overall creativity as the dependent variable and between-group factors for group interaction and problem-solving technique was significant, $F(7, 142) = 3.64$, $p < .001$, $\eta^2 = 0.15$. A planned contrast assessing the difference between interacting groups and nominal groups that used analogical reasoning revealed a significant difference. Interacting groups using analogical

[10] With Welch's adjustment for heterogeneous variances, the Hypothesis 6 planned comparison t statistic was t[35.035] = 2.58, p = .014.

reasoning produced solutions of higher overall creativity compared to nominal groups using analogical reasoning, (M = 3.83, SD = 0.36 vs. M = 3.51, SD = 0.33, t[142] = 3.28, $p < .01$)[11]. These results lend support to Hypothesis 8 and suggest that group interaction produces synergistic effects for analogical reasoning on overall creativity.

Summary of Hypotheses Tests

Table 9 shows the summary of findings for the hypotheses tests. The p values for the hypotheses tests are shown in the table.

SUPPLEMENTAL ANALYSES

I performed additional analyses to examine the pattern of test results when controlling for individualism, personality variables, and task conflict. I tested each of the hypothesized relationships controlling for variables that have been theorized to affect creativity, and that showed significant associations with dependent variables as indicated by the Pearson correlation data. I examined results from ANCOVA and used planned contrasts to assess whether hypotheses are supported when these variables are included. I used the methodology described in Jaccard (1998) for assessing planned contrasts; this method incorporates the covariate-adjusted means and the covariate-adjusted mean square error in each planned contrast analysis.

Table 10 shows the results of the covariate analyses. For each of H1-H4, I ran three different ANCOVA models: 1) adding individualism only, 2) adding task conflict only, and 3) adding all Big Five personality variables. For each of H5-H8, I ran the same models, except the task conflict models. Including task conflict as a covariate eliminates all the nominal groups from the analyses, and precludes assessment of H5-H8, which require nominal group data. Table 10 shows the overall F statistic for each ANCOVA

[11] With Welch's adjustment for heterogeneous variances, the Hypothesis 8 planned contrast t statistic was t[37.587] = 3.00, p = .005.

model, the F statistic for each covariate, and also whether the support status of each hypothesis changed due to inclusion of the covariates in the different models.

Individualism is significant in the first ANCOVA model for novelty, and openness to experience is significant in the third models for novelty and for overall creativity. However, the pattern of results obtained from the planned contrasts with covariates included is consistent with the results obtained from the original hypotheses tests. Thus, when controlling for individualism, personality variables, and task conflict, Hypotheses 1, 3, 4, 5, 6, 7, and 8 are still supported. These results show that including the covariates in the analyses does not change any of the substantive results of the study.

SUMMARY

The results of hypotheses tests, post-hoc analyses, and supplemental covariate analyses give support to the claims made earlier in this study related to the natural suitability of analogical reasoning as a distributed cognitive strategy that can be used by groups for functional creative outcomes. Interacting groups using analogical reasoning produced creative solutions of greater novelty, usefulness, and overall creativity compared to groups not using analogical reasoning. Also, interacting groups using analogical reasoning generated solutions higher in novelty, flexibility, usefulness, and overall creativity, compared to nominal groups composed of individuals using analogical reasoning. These findings for synergistic effects held across all dependent variables in the study. The overall pattern of results suggests that groups using analogical reasoning realized creative advantages over interacting groups not using analogical reasoning, and over nominal groups who used analogical reasoning. The substantive results of the study were not changed by including control variables for individualism, the Big Five personality dimensions, and task conflict.

Much of the theory put forward earlier explained the benefits of analogical reasoning in interacting groups by describing how analogical reasoning would help groups take advantage of their diverse knowledge and skills, stimulating divergent thinking and producing diverse knowledge contributions that lead to increased flexibility and novelty of products. The novelty data support this conjecture, while the flexibility data is mixed. On the other hand, the robust findings for solution usefulness indicate a relatively larger effect of analogical reasoning on usefulness, compared to the effects on novelty or flexibility.

The post-hoc analyses that compared interacting groups in different problem-solving conditions produced some interesting results. Interacting groups using analogical reasoning produced solutions of higher novelty compared to interacting groups who used analogy only, compared to interacting groups who used problem abstraction only, and compared to interacting groups who used brainstorming. Interacting groups using analogical reasoning also enjoyed a usefulness advantage over interacting groups in all three other problem-solving conditions. These findings held for overall creativity as well.

The overall pattern of findings for fluency in this study revealed that group interaction had the same production loss effect as has been replicated in many brainstorming studies (Mullen et al., 1991). In terms of idea production, nominal groups outperformed interacting groups in every problem-solving experimental condition, except for the analogy only condition, where the trend was consistent but the difference failed to reach statistical significance. It is likely that this production loss effect also influenced the flexibility data, because fluency is used in the denominator of the flexibility variable to adjust it for the number of ideas produced.

Finally, with the exception of the flexibility data, which displayed a nearly uniform advantage of group interaction across all problem-solving conditions, there was no evidence of synergistic effects for interacting groups in any problem-solving condition except for analogical reasoning. Analogical reasoning groups showed evidence of synergy for every dependent variable in the study.

Chapter 6: Discussion

Approach, Results, and Contributions

In this dissertation, I investigated group creativity by asking two basic questions. The first was a question about whether analogical reasoning is a relatively functional thinking approach for creative problem-solving performed by groups. The results of this study suggest that analogical reasoning may give interacting groups a creative advantage over other thinking strategies they might use, like following the rules of brainstorming (Osborn, 1953).

The second research question was a query about synergy in creative groups, and whether analogical reasoning in the context of group interaction might give rise to synergistic effects. This seems like a higher hurdle, based on other groups research (Larson Jr, 2010). Research in the brainstorming literature has sought the holy grail of group creative synergy for decades (Baruah & Paulus, 2009), but it has been a mostly fruitless search. The approaches that have been found to counteract production loss effects in brainstorming studies require a great reduction in group interaction, which theoretically cannot involve intermember synergistic effects (Dennis & Williams, 2003; Paulus & Yang, 2000).

My approach deviated from these types of studies in important ways. I rejected the notion that the brainstorming rules (Osborn, 1953) must be the primary cognitive strategy assessed, in part because brainstorming rules “are not rooted in any theory of the way the mind works” (Markman & Wood, 2009). I looked for a thinking technique that was not only functional for individual creative thinking, but that was also potentially well-suited to group collaboration, such that the combination of the cognitive strategy with group interaction might enable group members to leverage their diverse knowledge and information processing abilities. And finally, I looked for multiple indicators of group creativity instead of only examining ideational fluency, because fluency may not tell the whole story when it comes to interacting creative groups (Montag et al., 2012; Sutton & Hargadon, 1996). Results of the study suggest that some synergistic effects may be in play when interacting groups use analogical reasoning as a distributed cognitive strategy for solving creative problems.

An interesting overall result of the study was the strong experimental effects of group analogical reasoning on the usefulness of solution ideas. Much of the group creativity literature, as summarized in my own literature review in this study, draws on the basic assumption of the evolutionary model, which states that random variation plays a key antecedent role in the production of truly creative outputs. Variety of inputs leads to an increased chance of creative outputs (Staw, 2009). The results of this study suggest an interesting complementary possibility. Usefulness seemed to be just as critical as solution novelty, as a dimension of creative outputs, and analogical reasoning in interacting groups helped strongly promote it. These findings suggest that analytic and evaluative processes may not be as detrimental to group creativity as many have claimed (Amabile, 1996; Osborn, 1953), particularly if they arise in the context of group analogical reasoning.

The supplementary analyses that attempted to isolate the separate effects of the analogy only and problem abstraction only conditions and compare them to analogical reasoning produced some interesting results worthy of discussion. Interacting groups using analogical reasoning produced solutions of higher novelty compared to interacting groups in all three other problem-solving conditions. Interestingly, interacting groups in the analogy only condition produce solutions of significantly lower novelty compared to interacting groups in the other problem-solving conditions. This may indicate that interacting groups using analogy only were unable to achieve the same levels of abstract thinking related to the problem, compared to groups using analogical reasoning. Groups using problem abstraction only may not have had as much trouble in thinking about the problem abstractly, and this may have contributed to the novelty of their solution ideas, relative to interacting groups using analogy only. These results may point to the importance of an abstract problem schema for thinking divergently and generating novel solution ideas, particularly when groups try to use analogical thinking processes. The findings also suggest that the production of an abstract problem schema may not necessarily be an easy or guaranteed outcome, even if people have been exposed to analogical thinking techniques. Past research has shown that people are capable of generating an abstract problem schema solely from the comparison processes inherent in analogical mapping and solution inference (Gick & Holyoak, 1983). However, perhaps giving people independent advice on how to think abstractly about creative problems provides them an accelerated "head start" on the production of an abstract problem schema when combined with analogical thinking techniques. In other words, exposure to abstract thinking techniques may serve as a catalyst for engagement in analogical thinking processes. Participants in this study that were in the analogy only condition would not have experienced this catalytic, "head start" effect.

Interacting groups using analogical reasoning also enjoyed a usefulness advantage over both other types of interacting groups in the supplementary comparisons. The usefulness advantage over the groups using problem abstraction only might be a result of increased attention on goals and constraints produced by repetitive comparison processes inherent to mapping and solution inference. This explanation would predict that interacting groups using analogy only might also experience heightened attention to goals and constraints, and yet, they produced solutions that were also significantly lower in usefulness compared to groups using analogical reasoning. It could be that groups using analogy only were handicapped somewhat because they weren't exposed to techniques for thinking about problems abstractly, and again, perhaps this delayed or otherwise suppressed their ability to start using analogical processes in a functional, cyclical fashion. This would perhaps also explain why interacting groups using analogical reasoning produced solutions that were significantly higher on both novelty and usefulness, compared to interacting groups using analogy only.

Interacting groups using analogical reasoning produced solutions of higher overall creativity compared to interacting groups in all three of the other problem-solving conditions. An inspection of the overall pattern reveals that the effect size for overall creativity appears smaller than for usefulness or novelty. If creativity is a multidimensional construct that includes novelty and usefulness, then it is not readily apparent why the effect for overall creativity should be much smaller than the effects for its component dimensions.

This result may be due to the way that raters generated their overall creativity ratings in the study. As described in Appendix B, no guidance was given to the raters about how the combination of novelty and usefulness (for which they also generated ratings) should lead to an overall creativity rating. This lack of guidance follows the advice of some scholars in the creativity literature who claim independent raters must be free to use their own subjective evaluations for ratings of creativity (Amabile, 1982).

An examination of the cell means for novelty, usefulness, and overall creativity for interacting groups using analogical reasoning, interacting groups using problem abstraction only, and interacting groups using analogy only reveals that for all three conditions, raters discounted the overall creativity ratings compared to the average of the novelty and usefulness ratings[12]. This discounting appears to be greater for interacting groups using analogical reasoning than for the other two conditions. This difference in discounting brings overall creativity for analogical reasoning groups closer in value to the other two groups' overall creativity, and lessens the chances that post-hoc analyses will reveal differences. The point is that, in lieu of any compelling theoretical reasons to expect a difference in these comparisons for overall creativity, the answer may lie in methodological reasons, and it may have to do with how raters generated overall creativity ratings in parallel with novelty and usefulness ratings. Perhaps having raters do all three ratings in parallel changed the overall creativity ratings in some way, compared to some different method of collecting ratings where the overall creativity rating is performed in a more independent manner (e.g., using different raters, introducing a time lag after novelty and usefulness are rated, etc.).

The lack of findings for synergy among interacting groups using analogy only and problem abstraction only stand in stark contrast to the synergy findings for interacting groups using analogical reasoning. For novelty, usefulness, and overall creativity, interacting groups using analogical reasoning seemed to enjoy significant synergistic benefits over their nominal group counterparts. This synergy was completely absent across these dependent variables for interacting groups using either analogy only or problem abstraction only (or brainstorming). This may be the most significant overall finding of the study, because it suggests that there is something highly functional about the combination of analogical reasoning and group interaction that helps propel group

[12] During the meeting in which the definitions for novelty, usefulness, and overall creativity were discussed, one rater asked if they should average the ratings for novelty and usefulness to come up with the overall creativity rating for each solution idea. I told the raters that averaging novelty and usefulness was not required in order to generate their overall creativity ratings, and how they combined their perceptions of novelty and usefulness to generate an overall creativity ratings was up to them.

creative performance beyond what is possible with an aggregate of non-interacting individuals, even if they also attempt to use analogical reasoning.

The fluency results are typical of the many past studies in the brainstorming literature (Mullen et al., 1991). It is commonplace to find that group interaction produces process loss, and fluency is usually significantly lower for interacting groups compared to nominal groups. However, in this study these findings become interesting when combined with the findings for the other dependent variables. Interacting groups using analogical reasoning produced significantly fewer ideas than groups in any of the other seven experimental conditions. Yet, they also produced solution ideas that were significantly more novel, significantly more useful, and significantly more creative overall, compared to interacting groups in the other conditions. In some sense, interacting groups using analogical reasoning realized an efficiency advantage in this study, because their ideas were of relatively high quality even though there weren't as many of them, compared to those of interacting groups in the other experimental conditions. Even when comparing interacting groups using analogical reasoning with nominal groups across all other conditions, the data trends show that none of the nominal groups have a clearly significant advantage for novelty, usefulness, and overall creativity. Past brainstorming studies have typically found that a fluency advantage is associated with an idea quality advantage (Larson Jr, 2010), and that as a result, interacting groups have a difficult time competing with nominal groups when it comes to creative outcomes. This study makes an important contribution by revealing that a fluency advantage does not necessarily result in an idea quality advantage, when interacting groups use analogical reasoning.

The pattern of results for adjusted flexibility is better understood when taking the fluency results into account. Because adjusted flexibility is calculated with fluency in the denominator, part of the apparently uniform flexibility advantage for interacting groups over nominal groups may be due to the fact that nominal groups generally produced more ideas compared to interacting groups in this study. This means that at least part of the adjusted flexibility advantage observed for interacting groups may be due to an arithmetic artifact. The assumption that accompanies this possibility is that solution categories are exhausted relatively early on, and later ideas tend to represent solution categories that have already been elicited. This assumption is independent of the thinking strategy employed. Whether alternative thinking strategies like analogical reasoning may refute this assumption is still an unanswered question, although a re-analysis of the ordering of generated ideas in this study may potentially suggest an answer.

This study makes a contribution to the literature on group creativity by incorporating analogical reasoning into the theoretical approach and actually testing the theory with a suitable study design that can assess causal effects. Analogical reasoning has been well-studied in cognitive science at the individual level (Holyoak, 2012), and it is often invoked as a key cognitive process by theorists when discussing important collective creativity processes (Amabile, 1996; Hargadon, 1999; Hargadon & Bechky, 2006; Harvey, 2014; Shalley & Perry-Smith, 2008), but it is rarely operationalized and tested in organizational or small group research. Attempts at establishing analogical reasoning as a true group level, distributed cognitive processing system are also missing in the literature on group creativity. This study helps to rectify that.

Other points of possible connection and contribution

As I mentioned in the introduction, this study bears some theoretical similarities to the large literature on group cognition (Lewis & Herndon, 2011; Mohammed, Ferzandi, & Hamilton, 2010; Salas & Fiore, 2004; Wilson, Goodman, & Cronin, 2007). In particular, because creative problem-solving is primarily a thinking task, one could construe a deliberate strategy to use analogical reasoning in a group context as a type of shared mental model. In this case, it might be considered a meta-cognitive task mental model because it concerns what members know and how they think about their cognitive processing plan. Theorizing and conceptualizing the way people think about their cognitive processes has not been the focal point of much group cognition research (Hinsz, 2004). One might theorize, and the results of this study suggest, that to the extent all members of a group hold a similar meta-cognitive mental model of a group analogical reasoning approach, their interaction would be functional toward creative outcomes.

There is also an important distinction between the theoretical gist of shared mental model theory and analogical reasoning as a group thinking strategy. Shared mental model theory came about as a potential explanation for the highly effective coordination observed in action teams. What stunned researchers about these action teams was their ability to coordinate in fast-changing situations without the need for explicit verbal or other communication (Cannon-Bowers, Salas, & Converse, 1993). In fact, shared mental model researchers have argued that under conditions that allow free communication between members, shared mental models will not be that important (Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000). Clearly, there is a potential difference between traditional notions of shared mental models and the environments in which they are effective, and the conception of distributed analogical processing as a group creative thinking strategy. In the latter, free communication is a vital component of the meta-cognitive mental model. So while some obvious conceptual similarities exist between group analogical thinking and shared mental model theory, taking a shared mental model perspective with group analogical reasoning would probably serve to generate additional insights that arise due to the meta-cognitive quality of the analogical mental model and the differences between creative tasks and typical action team endeavors. This may serve to refine theoretical explanations, or in the case of shared mental model theory, produce some new ones.

Transactive memory represents another widely studied group cognitive construct that has some similarities with the notion of distributed group analogical reasoning (Wegner, 1987). Wegner promoted his transactive memory paradigm as a modern take on the "group mind" concept[13], a notion that was abandoned decades ago after failed efforts to effectively establish testable theory of the construct (Wegner, Giuliano, & Hertel, 1985). Unlike shared mental model theory, which eschews group communication as an important element of the construct's effects, TMS depends crucially upon it. Transactive memory processes include encoding, storage, and retrieval of critical task knowledge via intermember communications. Member cueing that stimulates knowledge retrieval from the memories of other members is a key part of the theory, and has strong similarities to my arguments about distributed analogical cognition in groups, and the way that members cue each other to stimulate the contribution of source analogs. But there are also some differences.

For one, TMSs typically arise and strengthen as a result of member experiences with each other. In fact, this is how TMSs are often manipulated or otherwise allowed to develop in experimental and correlational study designs in the small groups and management literatures (Lewis, 2004; Moreland, 1999). As members gain experience with one another on a task, they learn about the knowledge and skills of others, and this strengthens the TMS and naturally gives rise to the TMS processes. By contrast, shared experience is not a requirement for creative groups to successfully employ analogical reasoning as a distributed thinking strategy. A key difference involves the type of cueing

[13] Coincidentally, some have characterized the concept of "mind" as a system for generating ideas; this is precisely what creative groups do.

that happens in each framework. Members of a transactive memory system intentionally seek out specific knowledge from other members based on what they know about them and their past experiences. The cueing I theorize about in a distributed analogical reasoning system is not dependent on a shared history or targeted at retrieving particular knowledge from specific group members. There is no focused intent to the cueing, i.e., it arises naturally as a result of the problem abstraction process that accompanies analogical reasoning.

Still, one can make connections between TMS and distributed analogical reasoning and foresee some potential fruitful outcomes. While it is true that groups of strangers should be able to collaborate creatively using distributed analogical reasoning, one might theorize that members could come to gain a shared knowledge about each other that could heighten their performance. As I argued earlier, a group is likely to possess diversity of cognitive skills associated with the subprocesses of analogical reasoning. If members come to understand which other members have high proficiency with the various analogical subprocesses, even at an intuitive level, this could enhance their ability to collaborate using analogy and increase the collective's skill at producing novel and useful solution ideas. In this way, the group cognition characterizing the collective might change over time from a primarily isomorphic compositional construct (shared meta-cognitive mental model) to later include a more compilational model of the team and its complementary member abilities with reasoning analogically (Kozlowski & Klein, 2000). The concepts of transactive memory might thus be applied to the meta-cognitive aspects of collaborative analogical reasoning, and produce new theory that extends the current nascent thinking of how TMSs promote group creativity (Gino et al., 2010).

STUDY LIMITATIONS

One possible limitation of the study is the use of subjectively rated criterion variables, specifically, the ratings of novelty, usefulness, overall creativity, and solution categorizations. Great care was taken to ensure interrater agreement and consistency, and for most of these data the typical thresholds were met (LeBreton & Senter, 2008). In many creativity studies similar to this one, raters are considered to be "in agreement" if they give ratings within 1 scale number of each other, typically on a 5-point scale (among the many, some examples are Diehl & Stroebe, 1987; Rietzschel et al., 2006). I chose not to adopt this practice and instead spend extra time and effort with the raters to try and calibrate them to each other so they would use the ratings scales in a consistent manner. Still, the typical thresholds should be considered minimums. This limitation is not specific to this particular study, rather, it is inherent in many creativity studies that attempt to assess creativity with measures that go beyond simply looking at fluency. Still, it could be considered a limitation, and it applies to this study all the same.

It is rare to see group creativity studies in which novelty, usefulness, and overall creativity of outputs are reported. Other scholars have recently cited this as a weakness in the literature and called for this methodological practice in future studies of creativity (Montag et al., 2012). The intent in gathering data for all three variables in this study was meant to make a contribution on this issue. So, while the relationship between novelty, usefulness, and overall creativity in this study is perhaps slightly curious, as discussed earlier, reporting all three may make a contribution. Again, although recent guidance suggests this practice (Montag et al., 2012), this study may help future researchers think more about the methodological issues of having raters assign creative output scores for all three variables.

Another limitation concerns how effective the manipulations were in producing the desired cognitive strategies for analogical reasoning and abstract problem definition. Participants were encouraged via the written materials to use these strategies, and qualitative data gathered during the pilot study indicated that the analogical reasoning manipulation did work for many of the pilot study groups. However, the nature of the creative task and participants' familiarity with the topic of the problem (messy eating) seemed to instill in some interacting groups an instinct to try to solve the problem directly without resorting to the primed problem-solving strategies. This was observed by examining multiple video recordings. Many groups did ultimately use the strategies once the direct solution tactic was exhausted and idea production slowed, but it would perhaps have been a better test of the theory if a more effective way to instill the reasoning strategies could have been used. This limitation arose mostly due to the need to use a creative task that most people would have some familiarity with, so that special expertise would not be a necessity and creative idea production would not be hampered.

Another thorny methodological issue involved the coarseness of solution knowledge domain categorization and the slippage between solution categories and the source analog knowledge domains that gave rise to them. The knowledge domains from which source analogs are retrieved are the real intended targets of operationalized measures of divergent thinking. I foresaw this slippage and encouraged all participants to write down "where their ideas came from" on the Idea Sheets and with verbal task instructions. But compliance with this request was not uniform. Some groups and individuals wrote down many sources of inspiration while others wrote nothing down. It seems reasonable that some of the non-compliance was probably not purposive, because in some instances (perhaps many instances) it is difficult for a person to know precisely where an idea came from. This attempted additional measure of source analog knowledge domains did not work out, even though it may conceptually be a good indication of divergent thinking. The solution categorization method is one that has been used in multiple published brainstorming studies (Baruah & Paulus, 2008; Kohn & Smith, 2010; Nijstad et al., 2002, 2003), but in this study it may not quite have captured the phenomena for which it was intended.

Another obvious methodological limitation is one common to all laboratory studies that use undergraduate students. Ecological validity and generalizability to other populations is often at issue. Given the subject matter of this study, however, and the focus on cognitive operations of individuals and interacting groups, a laboratory study is not a bad design with which to start. The counterpart to this weakness is a strength of the study that all lab designs share: the ability to make causal claims based on randomized assignment to conditions (Shadish, Cook, & Campbell, 2002). Certainly any research program that hopes to make a contribution to organization science must at some point diversify its study designs so that plausible generalizability is within reach. On the other hand, a “proof of concept” for the basic cognitive effects is a valuable contribution as well.

A related limitation is that the role of expertise could not be assessed with this study design and sample (Markman & Wood, 2009). Expertise is clearly an important and variable factor for many organizational teams attempting to produce creative output and address specific problems grounded in a knowledge domain. Again, this is likely to be a goal of future studies in this research program, and longitudinal qualitative or survey-based designs are better research vehicles with which to assess the effects of expertise in creative organizational teams.

The focus on “cold cognition” is also somewhat limiting (Newell & Simon, 1972). Mood and emotion are important phenomena in groups (Kelly & Barsade, 2001), and they have implications for creativity according to theory and empirical findings (Amabile et al., 2005; George & Zhou, 2002, 2007; Isen et al., 1987). Group affect was validly captured in this study, but its post-task acquisition means it could only serve as a correlate of the criterion variables, and not a causal agent. Correlational data such as these can suggest measures and future study designs that incorporate latent construct measures as indicators of group process and emergent states, particularly for studies of organizational teams. Observations gleaned from these correlational data on positive and negative affect (among others) may also stimulate theory that leads to future lab studies that attempt to manipulate the variables of interest. Given the theoretical importance of emotion for creativity, a theoretical integration of affective constructs and group analogical distributed cognition is a viable possibility for the future, and one that has little precedent in studies of group creativity.

More generally, all the survey data in this study were captured at the end of the task activity, and as mentioned above for positive and negative affect, this introduces the possibility that responses to the survey items were influenced in some way by the completion of the task itself and by the experimental conditions to which participants were assigned, for both interacting group members and for individuals that completed the study. These data are more useful for theorizing additional dependent variables and process effects of the different experimental conditions, rather than being interpreted as additional causal factors that drove creative outcomes in this study.

PRACTICAL IMPLICATIONS AND CONCLUSIONS

In addition to making contributions to the group creativity literature, this study may suggest some insights for real organizations and managers of creative groups. Managers of interacting creative teams are tasked with establishing the team composition and the working context that will enhance creative outcomes and successful innovation. Popular wisdom expounds the value of non-evaluative contexts within which individuals can feel free to contribute diverse and unconventional ideas (Amabile, 1996, 1998; Osborn, 1953). The current study suggests a more nuanced view, and recent theory on collaborative creativity also questions the value of suppressing or eliminating an evaluative mindset in creative collectives (Harvey, 2014). It may be that managers should focus not only on composing teams with diverse knowledge and expertise about the subject matter of the task at hand, but should also consider more seriously the collaborative processes that creative group members use to generate, integrate, and evaluate their diverse inputs. This study suggests that the distributed thinking processes employed by creative groups may be just as important as the knowledge inputs they possess, in determining how effective they are at extracting and leveraging their collective cognitive assets.

Table 1: Manipulation check frequency data

Exp. condition	Response to manipulation check item							
	Brainstorming		Problem abstraction only		Analogy only		Analogical reasoning	
	Number	%	Number	%	Number	%	Number	%
BRS	104	100	0	0	0	0	0	0
PAO	0	0	105	100	0	0	0	0
AO	0	0	0	0	111	93	8	7
AR	0	0	0	0	4	3	125	97

Experimental condition key: BRS = Brainstorming; PAO = Problem abstraction only; AO = Analogy only; AR = Analogical reasoning.
Note: 2 participants failed to complete the manipulation check item in the post-task survey.

Table 2: Goals used for categorizing solution ideas

Goal Code	Goal
G01	prevent shell breakage
G02	contain/prevent/lessen the chances of a spill
G03	prevent liquid spills
G04	protect clothes
G05	change customer perceptions
G06	change customer behavior/choice
G07	acquire solution from outside the creative team
G08	help customer deal with spillage

Table 3: Means used for categorizing solution ideas

Means code	Means
M01	change design of shell
M02	use inedible external packaging or wrap
M03	change internal (not shell) ingredients
M04	protect clothes with barrier
M05	use edible outer "wrap"
M06	use holding device (not a wrap)
M07	use utensils to eat (no holding)
M08	change shell ingredients
M09	change dining furniture
M10	change overall taco size
M11	reinterpret the problem as "not a problem"
M12	shift responsibility or blame to customer
M13	advertising tactic/promotion
M14	generic taco design change
M15	change cooking process
M16	use customers as solution sources
M17	add a shell
M18	provide clothes that are "okay" to spill on
M19	provide cleaning materials
M20	"nudist" approach - remove clothes
M21	research to develop better shell or overall design
M22	competitive analysis
M23	give clothes a treatment that makes them stain proof
M24	change physics of falling objects (gravity elimination, etc.)

Table 4. Descriptive Statistics and Correlations

	Variables	Mean	SD	α‡	1	2	3	4	5	6	7	8	9†	10†	11†
1	Individualism	3.07	0.84	0.76											
2	Positive affect	3.15	0.45	0.89	-.09										
3	Negative affect	1.22	0.18	0.75	.12	-.13									
4	Extraversion	4.72	0.88	0.82	.07	.12	-.16								
5	Agreeableness	4.98	0.68	0.45	-.31**	.15	-.09	-.11							
6	Conscientiousness	5.74	0.58	0.51	.06	.04	-.21**	-.17*	.13						
7	Emotional Stability	5.21	0.73	0.67	-.16	.07	-.28**	-.03	.24**	.11					
8	Openness to Experience	5.13	0.70	0.48	.06	.34**	-.09	.27**	.12	.01	.01				
9	Cohesion†	6.01	0.49	0.80	.04	.55**	-.14	.13	.06	.04	-.06	.20			
10	Task conflict†	4.13	1.08	0.81	-.08	.24*	-.18	.25*	-.22*	-.18	.05	.00	.06		
11	Psychological Safety†	6.09	0.48	0.60	-.02	.55**	-.19	.08	.07	.04	-.21	.26*	.76**	.15	
12	TMS†	5.08	0.44	0.78	-.10	.50**	-.11	.17	.19	-.08	.05	.32**	.64**	.12	.55**

N = 150, except variables noted with † , which indicates N = 88 (interacting groups).
** p < .01; * p < .05 (2-tailed).
‡Alpha reliabilities for item level data, where applicable.

Table 4. Descriptive Statistics and Correlations (Cont'd)

	Variables	Mean	SD	α‡	1	2	3	4	5	6	7	8	9†	10†	11†
13	SD_Age	1.02	1.40		-.05	-.15	-.03	.10	.00	.10	.13	.10	-.21	-.11	-.22*
14	Blau_Gender	0.31	0.21		.07	-.18*	.20*	-.08	.04	-.07	.03	.05	-.31**	.03	-.14
15	Blau_Ethnicity	0.45	0.20		.09	.01	.20*	-.01	-.11	-.04	-.04	.15	.03	.16	-.02
16	Blau_First Language	0.22	0.26		.06	.03	.03	.03	-.10	-.15	-.08	.06	.12	.16	.11
17	Fluency	23.9	11.2		.22**	-.05	.06	-.01	-.08	-.08	-.22**	-.01	-.10	-.22*	.01
18	Flexibility	0.70	0.11		-.18*	.12	-.08	.04	.03	.12	.24**	.02	.14	.06	.00
19	Novelty	4.15	0.53		.17*	-.05	-.03	.06	-.17*	-.13	-.03	-.20*	-.09	-.04	-.01
20	Usefulness	4.33	0.62		-.14	.09	-.02	.19*	.04	-.04	.08	.05	-.07	.24*	-.13
21	Overall Creativity	3.63	0.31		-.03	-.10	.03	.05	-.01	-.10	.05	-.18*	-.09	.02	-.10

N = 150, except variables noted with † , which indicates N = 88 (interacting groups).
** $p < .01$; * $p < .05$ (2-tailed).
‡Alpha reliabilities for item level data, where applicable.

Table 4. Descriptive Statistics and Correlations (Cont'd)

	Variables	Mean	SD	α‡	12†	13	14	15	16	17	18	19	20
13	SD_Age	1.02	1.40		-.00								
14	Blau_Gender	0.31	0.21		-.05	.11							
15	Blau_Ethnicity	0.45	0.20		.08	-.01	.15						
16	Blau_First Language	0.22	0.26		.12	-.08	.04	.22**					
17	Fluency	23.9	11.2		-.07	.00	.01	-.04	-.04				
18	Flexibility	0.70	0.11		-.05	.06	-.12	-.03	.00	-.71**			
19	Novelty	4.15	0.53		-.04	-.07	-.04	-.11	.07	.31**	-.20*		
20	Usefulness	4.33	0.62		-.08	-.08	-.10	-.01	.02	-.36**	.31**	.12	
21	Overall Creativity	3.63	0.31		-.04	-.06	-.11	.04	-.02	-.06	-.06	.27**	.44**

N = 150, except variables noted with † , which indicates N = 88 (interacting groups).
** $p < .01$; * $p < .05$ (2-tailed).
‡Alpha reliabilities for item level data, where applicable.

Table 5: Novelty cell means and standard deviations

Novelty	Hypotheses tests conditions						Conditions for supplemental analyses					
	Brainstorming			Analogical Reasoning			Problem abstraction only			Analogy only		
	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n
Interacting groups	4.16[a]	0.34	22	4.51[ab]	0.40	22	4.19	0.51	22	3.74	0.57	22
Nominal groups	4.42	0.38	13	4.12[b]	0.56	18	4.35	0.64	13	4.18	0.50	18

Means that share a superscript are significantly different, $p < .025$ (2-tailed), and the difference was hypothesized.

Table 6: Flexibility cell means and standard deviations

Flexibility	Hypotheses tests conditions						Conditions for supplemental analyses					
	Brainstorming			Analogical Reasoning			Problem abstraction only			Analogy only		
	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n
Interacting groups	0.68	0.08	22	0.74[a]	0.12	22	0.71	0.13	22	0.69	0.10	22
Nominal groups	0.55	0.08	13	0.63[a]	0.13	18	0.56	0.14	13	0.63	0.12	18

Means that share a superscript are significantly different, $p < .025$ (2-tailed), and the difference was hypothesized.

Table 7: Usefulness cell means and standard deviations

Usefulness	Hypotheses tests conditions						Conditions for supplemental analyses					
	Brainstorming			Analogical Reasoning			Problem abstraction only			Analogy only		
	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n
Interacting groups	4.07[a]	0.34	22	5.18[ab]	0.40	22	4.12	0.37	22	3.93	0.38	22
Nominal groups	4.33	0.33	13	4.05[b]	0.61	18	4.15	0.50	13	4.24	0.53	18

Means that share a superscript are significantly different, $p < .025$ (2-tailed), and the difference was hypothesized.

Table 8: Overall Creativity cell means and standard deviations

	Hypotheses tests conditions						Conditions for supplemental analyses					
Overall Creativity	Brainstorming			Analogical Reasoning			Problem abstraction only			Analogy only		
	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n
Interacting groups	3.54[a]	0.17	22	3.83[ab]	0.36	22	3.52	0.26	22	3.62	0.33	22
Nominal groups	3.86	0.46	13	3.51[b]	0.33	18	3.74	0.29	13	3.60	0.31	18

Means that share a superscript are significantly different, $p < .025$ (2-tailed), and the difference was hypothesized.

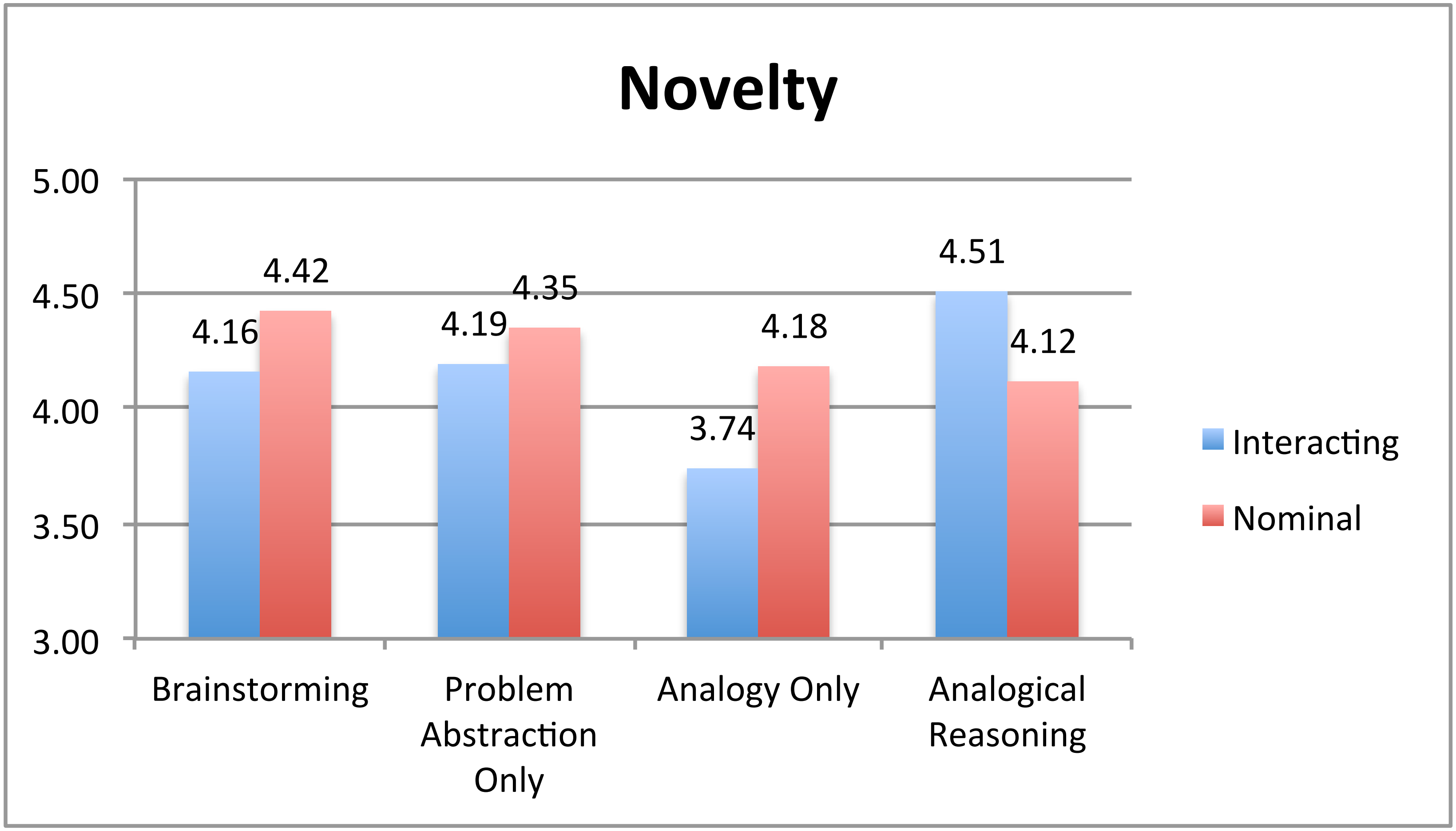

Figure 1. *Solution novelty group means across experimental conditions*.

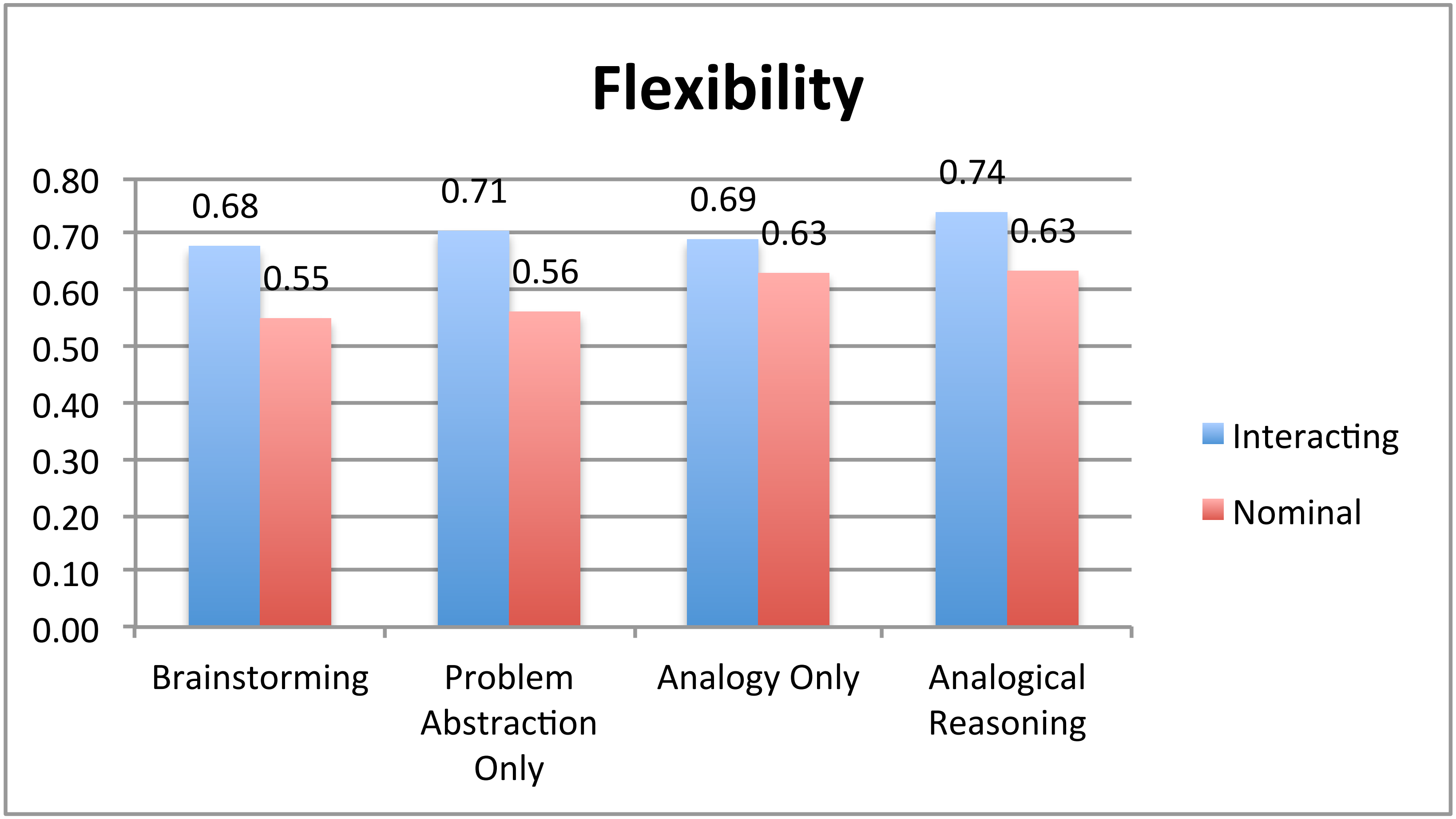

Figure 2. *Solution flexibility group means across experimental conditions*.

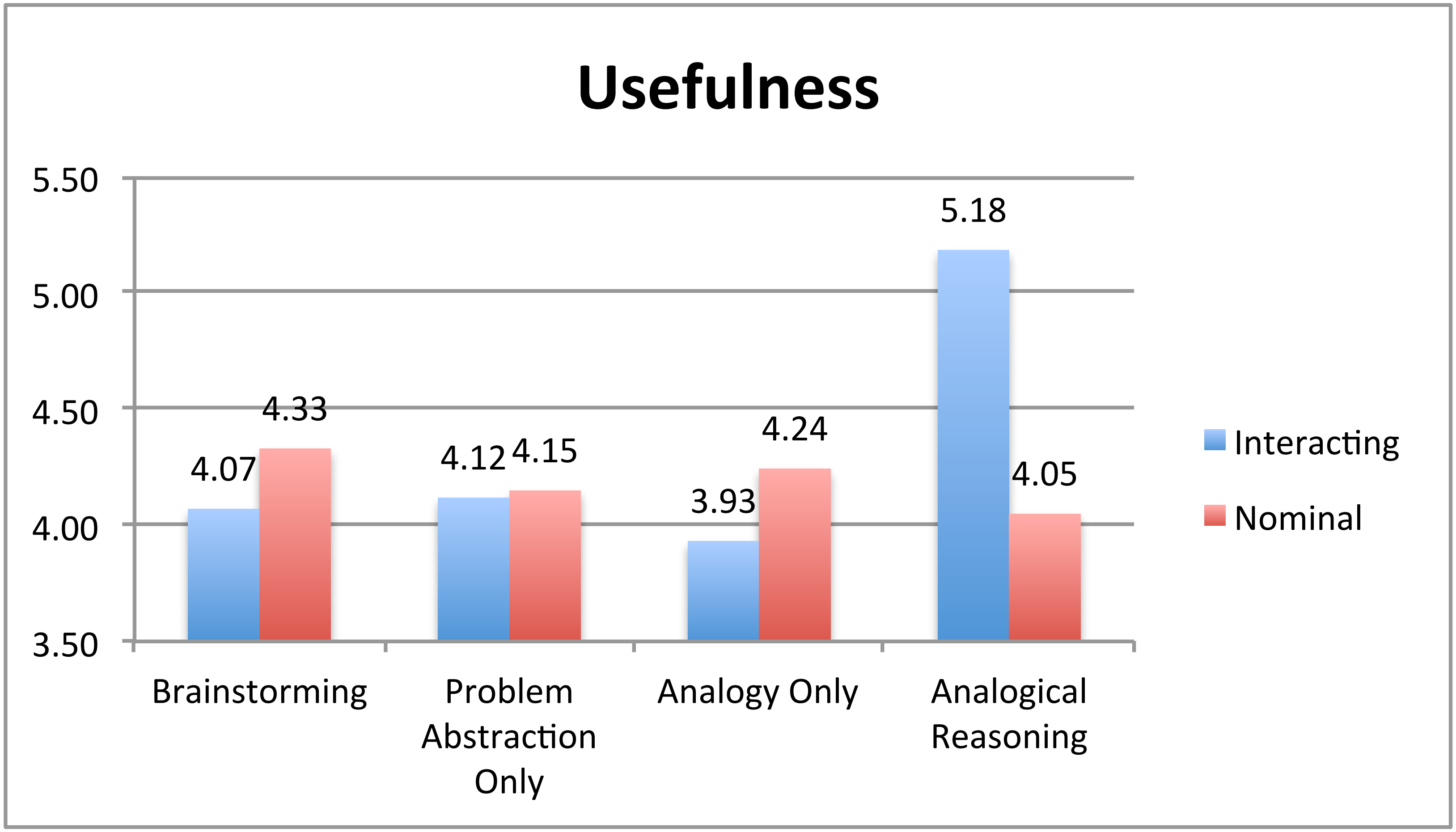

Figure 3. *Solution usefulness group means across experimental conditions*.

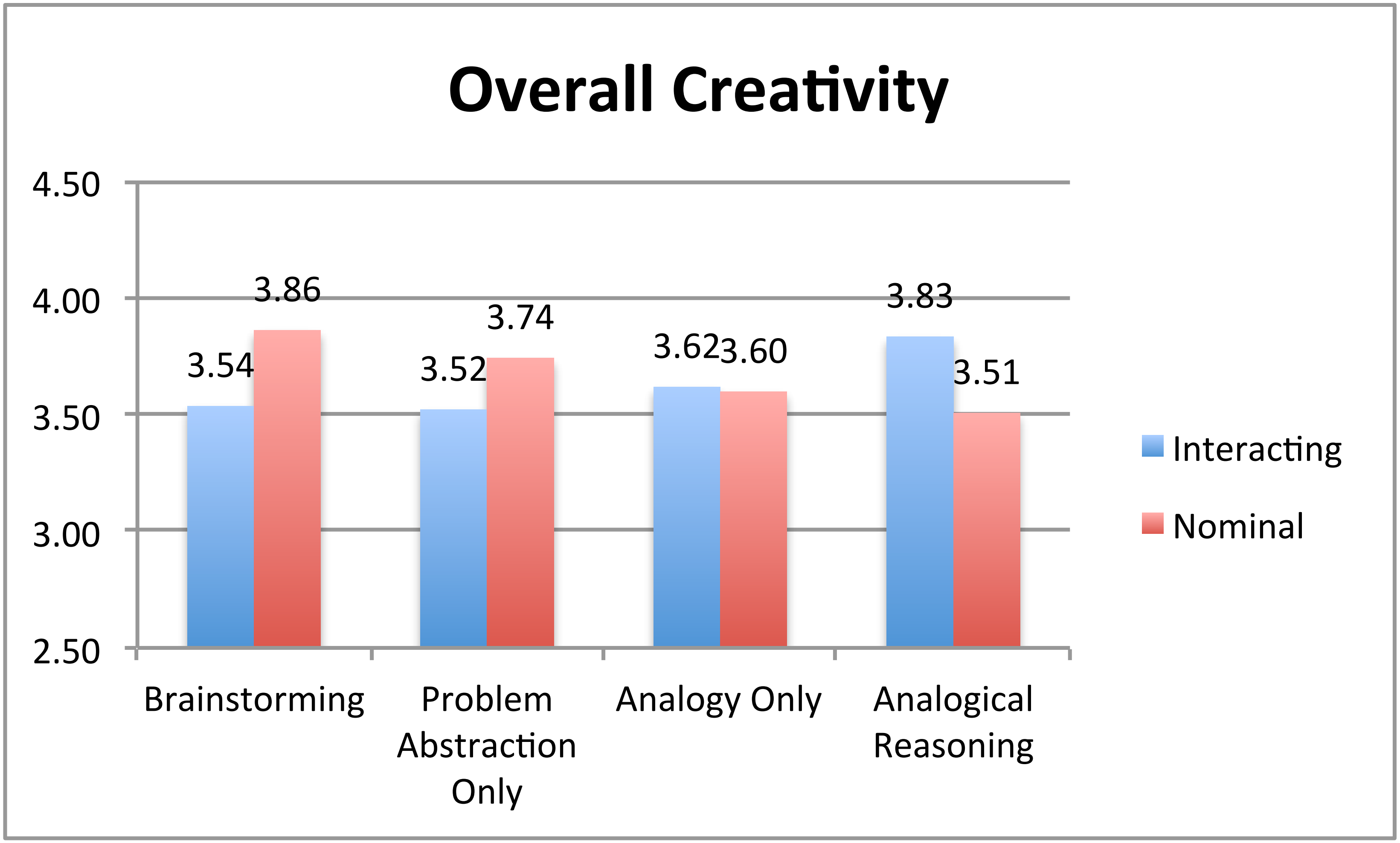

Figure 4. *Solution overall creativity group means across experimental conditions*.

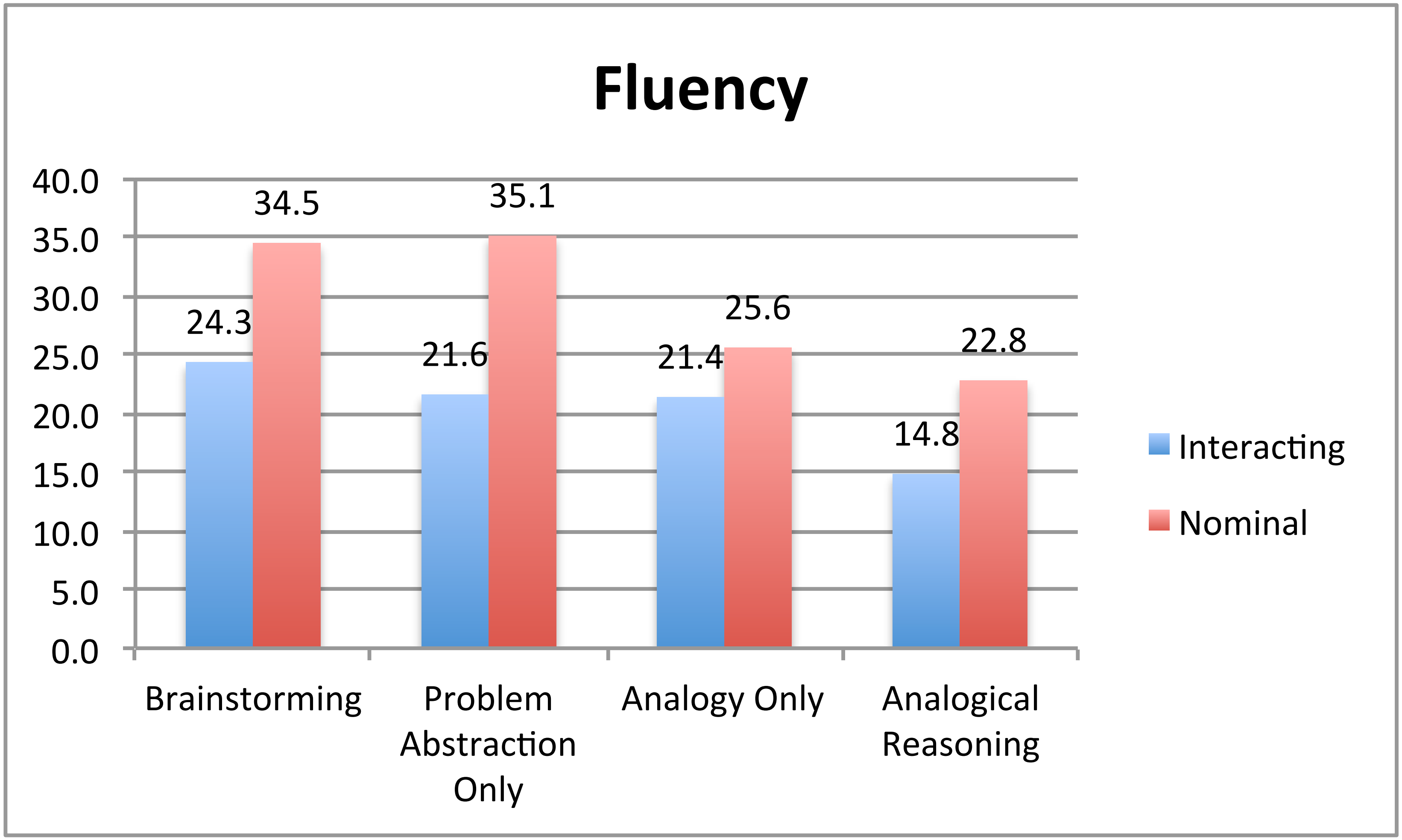

Figure 5. *Fluency group means across experimental conditions*.

Table 9: Summary of Findings for Hypotheses

Summary of Findings for Hypotheses			
No.	Hypothesis	p (2-tailed)	Support?
1	*Interacting groups using analogical reasoning will produce creative problem solutions of higher novelty compared to interacting groups not using analogical reasoning.*	.020	Y
2	*Interacting groups using analogical reasoning will produce creative problem solutions of higher flexibility compared to interacting groups not using analogical reasoning.*	.084	N
3	*Interacting groups using analogical reasoning will produce creative problem solutions of higher usefulness compared to interacting groups not using analogical reasoning.*	.000	Y
4	*Interacting groups using analogical reasoning will produce creative problem solutions of higher overall creativity compared to interacting groups not using analogical reasoning.*	.002	Y
5	*Interacting groups using analogical reasoning will produce creative problem solutions of higher novelty compared to nominal groups using analogical reasoning.*	.013	Y
6	*Interacting groups using analogical reasoning will produce creative problem solutions of higher flexibility compared to nominal groups using analogical reasoning.*	.014	Y
7	*Interacting groups using analogical reasoning will produce creative problem solutions of higher usefulness compared to nominal groups using analogical reasoning.*	.000	Y
8	*Interacting groups using analogical reasoning will produce creative problem solutions of higher overall creativity compared to nominal groups using analogical reasoning.*	.001	Y

Table 10: Summary of Findings for Hypotheses Tests with Covariates

Hypothesis	DV	Overall Model df	Overall Model F	Covariate(s)	Covariate F	Hypothesis df	t	p	Hypothesis (still) supported?†
1	Novelty	(8, 141)	4.87**	Individualism	5.27*	141	2.66	.009	Y
		(4, 83)	8.56**	Task Conflict††	2.78	83	2.78	.007	Y
		(12, 137)	3.60**	Extraversion	0.01	137	2.69	.008	Y
				Agreeableness	1.91				
				Conscientiousness	0.65				
				Emotional Stability	0.04				
				Openness to Exp.	5.43*				
2†	Flexibility	(8, 141)	4.89**	Individualism	0.12	141	1.78	.077	N
		(4, 83)	0.93	Task Conflict††	0.00	83	1.76	.082	N
		(12, 137)	3.77**	Extraversion	0.67	137	1.62	.108	N
				Agreeableness	1.61				
				Conscientiousness	1.62				
				Emotional Stability	2.29				
				Openness to Exp.	0.01				
3	Usefulness	(8, 141)	15.38**	Individualism	0.18	141	8.42	.000	Y
		(4, 83)	39.29**	Task Conflict††	0.01	83	8.50	.000	Y
		(12, 137)	10.38**	Extraversion	1.75	137	8.15	.000	Y
				Agreeableness	0.29				
				Conscientiousness	0.95				
				Emotional Stability	0.00				
				Openness to Exp.	0.01				
4	Overall Creativity	(8, 141)	3.24**	Individualism	0.48	141	3.06	.003	Y
		(4, 83)	4.46**	Task Conflict††	1.38	83	3.43	.001	Y
		(12, 137)	2.88**	Extraversion	0.01	137	3.36	.001	Y
				Agreeableness	0.25				
				Conscientiousness	0.53				
				Emotional Stability	0.97				
				Openness to Exp.	6.53*				

†Hypothesis 2 is unsupported in the original analyses without control variables.

††Task conflict data were only available for interacting groups. Therefore, the H1-H4 ANCOVA models that included task conflict utilized the covariate-adjusted means from interacting groups, and also used the mean square error term from the ANOVA with all eight experimental groups included in computing the mean square error terms.

F statistics: $^{*}p < .05$; $^{**}p < .01$

Table 10 (cont'd): Summary of Findings for Hypotheses Tests with Covariates

Hypothesis	DV	Overall Model df	Overall Model F	Covariate(s)	Covariate F	Hypothesis df	t	p	Hypothesis (still) supported?
5	Novelty	(8, 141)	4.87**	Individualism	5.27*	141	3.04	.003	Y
		(12, 137)	3.60**	Extraversion	0.01	137	2.51	.013	Y
				Agreeableness	1.91				
				Conscientiousness	0.65				
				Emotional Stability	0.04				
				Openness to Exp.	5.43*				
6	Flexibility	(8, 141)	4.89**	Individualism	0.12	141	2.91	.004	Y
		(12, 137)	3.77**	Extraversion	0.67	137	2.68	.008	Y
				Agreeableness	1.61				
				Conscientiousness	1.62				
				Emotional Stability	2.29				
				Openness to Exp.	0.01				
7	Usefulness	(8, 141)	15.38**	Individualism	0.18	141	8.09	.000	Y
		(12, 137)	10.38**	Extraversion	1.75	137	8.01	.000	Y
				Agreeableness	0.29				
				Conscientiousness	0.95				
				Emotional Stability	0.00				
				Openness to Exp.	0.01				
8	Overall Creativity	(8, 141)	3.24**	Individualism	0.48	141	3.12	.002	Y
		(12, 137)	2.88**	Extraversion	0.01	137	3.12	.002	Y
				Agreeableness	0.25				
				Conscientiousness	0.53				
				Emotional Stability	0.97				
				Openness to Exp.	6.53*				

F statistics: $^{*}p < .05$; $^{**}p < .01$

APPENDIX A: MATERIALS

Materials are presented in the following order, and each set of materials in the Appendix is referenced by its outline number/letter combination below, e.g., 1.a, 3.a.i, etc.

1. Task Instruction Sheet
    a. Experimental condition: Interacting Groups
    b. Experimental condition: Nominal Groups
2. Idea Sheet
    a. Experimental condition: Interacting Groups
    b. Experimental condition: Nominal Groups
3. Experimental manipulation materials
    a. Experimental condition: Interacting Groups
        i. Experimental condition: Brainstorming
        ii. Experimental condition: Problem abstraction only
        iii. Experimental condition: Analogy only
        iv. Experimental condition: Analogical reasoning
    b. Experimental condition: Nominal Groups
        i. Experimental condition: Brainstorming
        ii. Experimental condition: Problem abstraction only
        iii. Experimental condition: Analogy only
        iv. Experimental condition: Analogical reasoning

Factor 1

	Brainstorming	Problem abstraction only	Analogy only	Analogical reasoning
Interacting Groups	3.a.i	3.a.ii	3.a.iii	3.a.iv
Nominal Groups	3.b.ii	3.b.ii	3.b.iii	3.b.iv

Factor 2

Figure A1. Outline numbering guide to experimental manipulation conditions and materials presented in Appendix A.

TASK INSTRUCTIONS [1.a: INTERACTING GROUPS]

A popular Mexican fast food restaurant has hired your team to help them solve an important problem. They've recently introduced a new, different hard shell taco that is very popular with their customers, but they've gotten a lot of feedback from customers that indicates a problem.

Customers are complaining that, even though the tacos are delicious, they fall apart too easily when the customers eat them, AND – this tends to mess up their clothes. Customers are spilling taco contents all over their shirts and pants when they eat the new tacos.

YOUR CREATIVE PROBLEM-SOLVING TASK

Work together as a team to think of as many ideas as you can that might solve this "fragile taco/messy clothes" problem. The goal is to help customers keep their clothes from getting messed up, while also preserving the deliciousness of the tacos as best you can.

GENERAL TIPS FOR CREATIVE THINKING

We want you to be as creative as you can be. Creative ideas usually have some element of NOVELTY to them, i.e., they are unique and unusual in some way.

The following tips usually help for creative thinking:

1. Try to generate **as many ideas as you can**
2. **Try to think broadly**, i.e., "think outside the box"
3. **Write ALL your ideas down**, and
4. **Indicate where the ideas came from**
5. It's okay to provide a sketch or basic drawing if you want (but don't spend too much time on this)

FINALLY – A **REMINDER**: please remember to WRITE EVERY IDEA DOWN, even if you later decide it doesn't seem like a good solution because it's too crazy or weird. And, make sure to WRITE DOWN WHERE YOU GOT THE IDEA FROM, e.g., if you remembered something else that led you to the idea.

TASK INSTRUCTIONS [1.b: NOMINAL GROUPS]

A popular Mexican fast food restaurant has hired you to help them solve an important problem. They've recently introduced a new, different hard shell taco that is very popular with their customers, but they've gotten a lot of feedback from customers that indicates a problem.

Customers are complaining that, even though the tacos are delicious, they fall apart too easily when the customers eat them, AND – this tends to mess up their clothes. Customers are spilling taco contents all over their shirts and pants when they eat the new tacos.

YOUR CREATIVE PROBLEM-SOLVING TASK

Try to think of as many ideas as you can that might solve this "fragile taco/messy clothes" problem. The goal is to help customers keep their clothes from getting messed up, while also preserving the deliciousness of the tacos as best you can.

GENERAL TIPS FOR CREATIVE THINKING

We want you to be as creative as you can be. Creative ideas usually have some element of NOVELTY to them, i.e., they are unique and unusual in some way.

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FINALLY – A **REMINDER**: please remember to WRITE EVERY IDEA DOWN, even if you later decide it doesn't seem like a good solution because it's too crazy or weird. And, make sure to WRITE DOWN WHERE YOU GOT THE IDEA FROM, e.g., if you remembered something else that led you to the idea.

IDEA SHEET **[2.a: INTERACTING GROUPS]**

Please describe your idea (a crude sketch is okay if you want to provide it):

Where did this idea come from, i.e., how did your team think of it?

IDEA SHEET **[2.b: NOMINAL GROUPS]**

Please describe your idea (a crude sketch is okay if you want to provide it):

Where did this idea come from, i.e., how did you think of it?

(MANIPULATION: 3.a.i: INTERACTING GROUP/BRAINSTORMING CONDITIONS)

Today, you and your teammates are going to work together to think of creative solutions to a problem.

Before you get your problem, we want you to read a couple of internet blog entries that discuss *brainstorming* – a technique for generating ideas.

[BRAINSTORMING BLOG NUMBER ONE]
Brainstorming…Fast and Fun!

How many times have you come out of a brainstorming session feeling unsatisfied with the results? The team never felt like it got into a rhythm. The idea flow felt like a drizzle versus a storm. None of the ideas that the team spent much time on seemed especially good (BTW, you should never spend a lot of time on any one idea in a brainstorming session). There was one or two people that insisted on dominating the conversation and ended up speaking way too much. This to the frustration of the rest of the group. The good news is that there are just a handful of things you need to do to run a productive and fun brainstorming session.

The overall goal of any brainstorming is to generate a high quantity of ideas. This is really important … **it's all about quantity, NOT quality**. You will have plenty of opportunity after brainstorming to evaluate the quality of the ideas generated and select a winner.

So if our goal is quantity, what strategies can we employ to accomplish this? Well, we want to eliminate as many barriers to idea flow as we can. **The two main barriers to idea flow are stress/tension and the left-brain's need to constantly evaluate things**. When you are stressed, it is very difficult to think about anything else other than that feeling of stress and maybe what is causing it. Therefore, our strategy is to be relaxed and to conduct the brainstorming at such a fast pace, that the left-brain doesn't have time to interrupt our flow.

When brainstorming, the process is broken up into three parts:

- Setting the Stage
- Idea Generation
- Evaluating the Ideas (only if there is time)

SETTING THE STAGE

This is when you communicate the objectives, set the tone for the brainstorming, and instruct everyone on how it will be run.

Make the objective Clear

Ensure that everyone in the room clearly understands what the purpose of the brainstorming is. What is the issue that you are all generating ideas for? Write it down as a title at the top of the whiteboard or computer screen.

Setting the Tone

Like I mentioned before, you want the meeting to be **relaxed and light-hearted**, but at the same time its purpose should be very clear.

It's your facial expressions, body language, and tone that will have the biggest effect over how relaxed the team will be going into the brainstorming session.

Prior to the meeting, do those things that relax you and put you into a great mood. It could be avoiding that extra cup of coffee, waiting until later to read that upset email from a customer, or reading Dilbert. Figure out what works for you and do it. You should also anticipate that the session will be fun and productive. This "positive visualization" technique used by athletes is very applicable here.

Smile. If you are already relaxed this won't be hard, and you certainly don't want to force one. If you smile when explaining how this session will be run, everyone will be more relaxed about it.

This may or may not work for you, but I used to keep a box of toys which I would bring with me to every brainstorming session. It would contain colorful and simple physical puzzles. The idea was that toys automatically set a more light-hearted tone in the room. They also gave people something to fiddle with and didn't require any of their real mental capacity, which I wanted them to save for idea generation.

Brainstorming Instructions

No matter if this is the first, second, tenth, or hundredth session you have had with this group, always start by reviewing the ground rules for the session. It helps to establish the pace you are after, and it minimizes the chances of anyone being offended by any actions during the session.

These are the instructions you should provide the team before brainstorming begins.

- Our goal is to fill this [screen | whiteboard | paper] with as many ideas as possible.
- The faster we can generate ideas, the better. Let them flow!
- Any and every idea is welcome, including the crazy ones
- Don't provide any negative or positive critique of any idea.
- Mis-spelled words are ok. Don't break our rhythm to provide spelling corrections.
- The wrong organization of ideas is ok. When the ideas are captured in an outline or mind map, it is ok if ideas go in the wrong place. That can be fixed later.
- No one idea will be discussed longer than 10 seconds. Anything that requires more will be listed on the "Discussion List". The team will return to items on this list when idea generation is done. We do this because we want to maintain momentum.
- Interruptions are ok, and even encouraged, so speak up.
- And HAVE FUN!

RUNNING THE ACTUAL BRAINSTORMING SESSION

Plan to capture the ideas in a way that is comfortable and fast for you, and visible to the entire team. You could use the whiteboard, a large pad of paper, or in Word or Excel (Pages or Numbers for us Mac folks). Whichever you use is fine, just make sure you are totally fast and comfortable. The last thing you want to do is slow down the team because you are struggling with the tool.

Say the first few ideas and capture them quickly. Prior to the meeting, try to have some ideas in your hip pocket. You will use them to **prime the pump**.

If no one else offers up any ideas right away, turn to the team with the best look of anticipation you can muster. If still nothing, quickly adding some additional ideas of your own. Do this a couple of times and the ideas should start coming.

You should be quickly writing or typing the ideas. This will convey the fast pace you wish to achieve in the brainstorming.

If anyone breaks a rule such as criticizing ideas or correcting spelling, just provide a quick and gentle reminder that it isn't necessary and move on.

If anyone begins to settle into a long description of an idea, just say "that's good stuff, but we need to keep our momentum going. Let's come back to that". Then make note of it on the "Discussion List", and then encourage the team to start generating ideas again.

If you find yourself struggling to capture all the ideas because they are coming so fast … Congratulations, you are running a fantastic brainstorming session! Let yourself smile in a big way and let the team see that. It's great positive reinforcement for everyone in the room.

WRAPPING UP THE SESSION

A really productive brainstorming session usually runs no more than 30 minutes. I wouldn't put a time constraint on it though. Just let it run out on its own. Once the team has decided that idea generation is done, return to those items that were put on the Discussion List. Let people finish expressing the thoughts that they had earlier. This could lead to a few more ideas being captured. Depending on the amount of time remaining, the team may want to identify which of the ideas are the best. You can do it together as a group or individually after the meeting is done.

But remember, that long list of ideas was the deliverable you were going after. Having it means that your brainstorming session was a success.

SUMMARY

The best way to run a productive brainstorming session is to make it fast and fun. You make it fun by getting yourself and the team into a relaxed state. And you make it fast so that your left-brain doesn't have time to stifle your right-brain's creativity.

And remember, to come up with a few high-quality ideas, you must first produce a high-quantity of ideas. So play the numbers game and generate lots of ideas during your brainstorming sessions.

Good luck, and have fun!

See more at:
<http://www.innovationexcellence.com/blog/2012/03/23/brainstorming-fast-fun/#sthash.9PsYwipp.dpuf>

[BRAINSTORMING BLOG NUMBER TWO]
6 Tips for More Productive Brainstorming Sessions

You're sitting down with people throwing ideas around. You're writing stuff down more than usual. You're keeping an eye out for a standout idea that you can roll with. You're storming that brain. You're brainstorming.

The generation of ideas, to any team, is no doubt important. For example, at Design Instruct, we meet and talk about future projects, we throw around ideas about artists we like and the work they do, we attempt to come up with fresh content ideas and new site features, and so on. Brainstorming is an important part of what we do.

Throughout the course of working closely together, we've discovered a few tips and tricks that often lead to great ideas after a brainstorming session. We thought we'd share some of them with you.

1. Create a Positive Atmosphere for Your Brainstorming Session

It's easy to think of meetings as boring, dreadful, painful and anxiety-inducing periods of time. Oftentimes, as a meeting participant or facilitator, you wish you could be doing something else. Sometimes people get called out, put on the spot, and fingers get pointed. Meetings are frequently perceived to be boring because they're repetitive and drudgingly systematic.

If you want to conduct an effective brainstorming session, it's important that the atmosphere is fun, positive, welcoming and judgment-free. This way, the meeting participants won't hesitate to share their ideas for fear of ridicule or reprimand from their peers.

2. Lay Out the Ground Rules

Clarity. It's sort of become a buzzword around the office for us. Clarity is a virtue. It's the starting point for most of what we do.

It's often said that there are no bad ideas in brainstorming. This is true. But there are ideas that just waste time and produce no actionable outcomes at all. These are the "ideas" that people throw out there to be funny or to add levity with no real substance.

Remember this: Respect the process of generating ideas. Otherwise, you're just wasting everyone's time.

You have to keep brainstorming focused. Do this by clarifying the objectives and the goals of a new project, and have everyone start from that point of clarity.

If what we're trying to achieve is clear, then every idea born out of a brainstorming session also inherits that same clarity.

At the end of your brainstorming session, you'll be left with a few really good ideas, and the only decision you need to make is to pick out the best ones to move forward with.

3. Don't Overlook Ideas that Aren't Everyone's Favorite

As long as an idea adheres to the objectives and the goals of the project, it should be considered as a viable option.

At the very least, you should look at an idea as a jumping-off point for other ideas. Or you can take all these not-so-good ideas and synthesize them into one really good one; a sort of Frankenstein's monster of an idea.

4. Throw Away Ideas that Just Won't Work
Sometimes we get attached to ideas we come up with just by the mere fact that we came up with it. I do it all the time. I fall in love with an idea because I think it's clever or cool or I think it will be a hit, even if all indications point to the contrary.

However, again, be clear about what you need from the idea.

Not every idea you come up with will be a hit. That's impossible. In fact, I think most of you will agree that most ideas you come up with aren't going to be good. Therefore, you have to get rid of all of them. Throw them out there, put these ideas on the table and let them go. Let them float into the ether and be done with it. Those ideas were never yours to begin with. They're just vague abstractions: Notions that may have seemed good in your head, but with no real substance or no real chance of being successful.

The only time you can claim an idea as yours is when it's good enough for you to put it into action. That's the only time an idea actually starts to exist. It only becomes tangible and concrete when there's a chance of it being successful.

5. Don't Tune Out When Things Don't Go Your Way
Sometimes you won't agree with the direction the idea-generation process is taking. And if you're like me, your stubbornness and hardheadedness will tell you to just tune out, stop listening and stop contributing.

Fight the urge to shut off from the brainstorming session!

No good can come from shutting down. By not participating, you've just cut the team's efficacy by one person. That's one less brain, one less idea, and one less thoughtful insight.

Tuning out is not good for the brainstorming atmosphere. It isn't good for morale.

Try this instead: Voice out what's bothering you about the brainstorming session**.** It won't matter if you get angry or too impassioned with what bothers you. In fact, it might help the group better understand the pitfalls of the direction they're headed.

Think about it this way: If someone disagrees, it means that the idea in question isn't completely solid. There are still holes to be filled. The fact that you disagree is ultimately good for the outcome of the project.

6. Pragmatism First, Vision (Immediately) Second
Let's face it: You need to achieve something with your ideas. That's what brainstorming is for. You address some issues and you formulate solutions. It's immediate. Your project is the task at hand. Therefore, you have to treat it as such.

Don't let your idea get bigger than it needs to be right now.

Most creative people have great vision. Ideas will sometimes get out of hand, and they become these big, world-changing, life-defining things that get cumbersome and unwieldy when you do try to move them into action.

Some of the biggest ideas today started out very small and simple. However, if you study these ideas (e.g. Google's search, Apple's products, etc.) you'll see that they started out from a place of clarity. They addressed specific needs and objectives. They were simple. Start there with your idea and let it grow.

Vision is important, but it can't be the driving force behind the actual work and the time that needs to be put into getting an idea off the ground.

Vision is limitless for many people, and that's never helpful when you have real, immediate objectives and needs for a project.

Vision merely guides an idea. Pragmatism is the thing that pushes it forward.

Share Your Own Brainstorming Session Tips!
- How does your company produce ideas in teams?
- In your experience, what strategies and techniques yield better and more productive brainstorming sessions?

Did you apply any of the tips mentioned above in your last brainstorming session?

See more at: <http://designinstruct.com/articles/project-management/tips-productive-brainstorming-sessions/>

<u>We would like you to use these ideas about brainstorming today to help solve the creative problem we give you.</u>

(MANIPULATION: 3.a.ii: INTERACTING GROUP/PROBLEM ABSTRACTION ONLY CONDITIONS)

Today, you and your teammates are going to work together to think of creative solutions to a problem.

Before you get your problem, we want to teach you some thinking techniques that we would like your group to use. They involve using brainstorming techniques and thinking about problems in an abstract way.

Brainstorming…Fast and Fun!

How many times have you come out of a brainstorming session feeling unsatisfied with the results? The team never felt like it got into a rhythm. The idea flow felt like a drizzle versus a storm. None of the ideas that the team spent much time on seemed especially good (BTW, you should never spend a lot of time on any one idea in a brainstorming session). There was one or two people that insisted on dominating the conversation and ended up speaking way too much. This to the frustration of the rest of the group. The good news is that there are just a handful of things you need to do to run a productive and fun brainstorming session.

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This is when you communicate the objectives, set the tone for the brainstorming, and instruct everyone on how it will be run.

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It's your facial expressions, body language, and tone that will have the biggest effect over how relaxed the team will be going into the brainstorming session.

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Smile. If you are already relaxed this won't be hard, and you certainly don't want to force one. If you smile when explaining how this session will be run, everyone will be more relaxed about it.

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These are the instructions you should provide the team before brainstorming begins.

- Our goal is to fill this [screen | whiteboard | paper] with as many ideas as possible.
- The faster we can generate ideas, the better. Let them flow!
- Any and every idea is welcome, including the crazy ones
- Don't provide any negative or positive critique of any idea.
- Mis-spelled words are ok. Don't break our rhythm to provide spelling corrections.
- The wrong organization of ideas is ok. When the ideas are captured in an outline or mind map, it is ok if ideas go in the wrong place. That can be fixed later.
- No one idea will be discussed longer than 10 seconds. Anything that requires more will be listed on the "Discussion List". The team will return to items on this list when idea generation is done. We do this because we want to maintain momentum.
- Interruptions are ok, and even encouraged, so speak up.
- And HAVE FUN!

RUNNING THE ACTUAL BRAINSTORMING SESSION

Plan to capture the ideas in a way that is comfortable and fast for you, and visible to the entire team. You could use the whiteboard, a large pad of paper, or in Word or Excel (Pages or Numbers for us Mac folks). Whichever you use is fine, just make sure you are totally fast and comfortable. The last thing you want to do is slow down the team because you are struggling with the tool.

Say the first few ideas and capture them quickly. Prior to the meeting, try to have some ideas in your hip pocket. You will use them to **prime the pump**.

If no one else offers up any ideas right away, turn to the team with the best look of anticipation you can muster. If still nothing, quickly adding some additional ideas of your own. Do this a couple of times and the ideas should start coming.

You should be quickly writing or typing the ideas. This will convey the fast pace you wish to achieve in the brainstorming.

If anyone breaks a rule such as criticizing ideas or correcting spelling, just provide a quick and gentle reminder that it isn't necessary and move on.

If anyone begins to settle into a long description of an idea, just say "that's good stuff, but we need to keep our momentum going. Let's come back to that". Then make note of it on the "Discussion List", and then encourage the team to start generating ideas again.

If you find yourself struggling to capture all the ideas because they are coming so fast …

Congratulations, you are running a fantastic brainstorming session! Let yourself smile in a big way and let the team see that. It's great positive reinforcement for everyone in the room.

WRAPPING UP THE SESSION

A really productive brainstorming session usually runs no more than 30 minutes. I wouldn't put a time constraint on it though. Just let it run out on its own. Once the team has decided that idea generation is done, return to those items that were put on the Discussion List. Let people finish expressing the thoughts that they had earlier. This could lead to a few more ideas being captured. Depending on the amount of time remaining, the team may want to identify which of the ideas are the best. You can do it together as a group or individually after the meeting is done.

But remember, that long list of ideas was the deliverable you were going after. Having it means that your brainstorming session was a success.

SUMMARY

The best way to run a productive brainstorming session is to make it fast and fun. You make it fun by getting yourself and the team into a relaxed state. And you make it fast so that your left-brain doesn't have time to stifle your right-brain's creativity.

And remember, to come up with a few high-quality ideas, you must first produce a high-quantity of ideas. So play the numbers game and generate lots of ideas during your brainstorming sessions.

Good luck, and have fun!

See more at:
<http://www.innovationexcellence.com/blog/2012/03/23/brainstorming-fast-fun/#sthash.9PsYwipp.dpuf>

Thinking about problems in an abstract way

In creative problem solving, it is often important to consider how you define the problem itself. Thinking of the problem in an abstract way can often help your group be creative. By abstract, we mean that you think very generally about the underlying problem situation, without focusing on specific details that are part of the problem.

For example, suppose you work for a packaging design firm, and you find out that grocery shoppers commonly complain that they often buy more groceries than they can fit in the reusable grocery bags that they take in the store. From this situation, you are given the following specific design problem:

> (Specific problem): You need to design a new kind of reusable grocery bag that will stretch to fit more groceries inside it.

Now, to think of this more abstractly, we can restate the problem by replacing specific words with more general words:

> (More abstract!): You need to design a new kind of shopping bag that will expand to fit more shopping items inside it.

Now, even more abstractly, we can write:

> (Even more abstract!): You need to design a new kind of container that can change to fit more items inside it.

Now, here's why this thinking technique helps: abstract problem statements sometimes remind you of other specific examples that fit the abstract statements. Those specific examples might give you some creative ideas about how to solve the actual problem you're working on.

We'd like you to practice this abstract technique so that we know you understand how to do it. Take the following specific problem and write it in an abstract form, and then in an even more abstract form:

> (Specific problem): You need to design a new kind of outdoor urban garden hose that stretches out and gets long when the cold water supply is turned on, but that also shortens and takes up very little space when the cold water supply is turned off.

> (More abstract! → finish this definition): You need to design a

> (Even more abstract! → finish this definition): You need to design a

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<u>We would like you to use abstract problem definition techniques and these ideas about brainstorming today to help solve the creative problem we give you.</u>

<u>[NOTICE: THIS MANIPULATION EXAMPLE PAIRS THE PROBLEM ABSTRACTION ONLY READING WITH BRAINSTORMING BLOG NUMBER ONE. BRAINSTORMING BLOG NUMBER TWO WAS ALSO USED WITH THE PROBLEM ABSTRACTION ONLY READING, BUT THAT COMBINATION IS OMITTED HERE TO SAVE SPACE]</u>

(MANIPULATION: 3.a.iii: INTERACTING GROUP/ANALOGY ONLY CONDITIONS)

Today, you and your teammates are going to work together to think of creative solutions to a problem.

Before you get your problem, we want to teach you some thinking techniques that we would like your group to use. They involve using brainstorming techniques and using analogical thinking.

Brainstorming…Fast and Fun!

How many times have you come out of a brainstorming session feeling unsatisfied with the results? The team never felt like it got into a rhythm. The idea flow felt like a drizzle versus a storm. None of the ideas that the team spent much time on seemed especially good (BTW, you should never spend a lot of time on any one idea in a brainstorming session). There was one or two people that insisted on dominating the conversation and ended up speaking way too much. This to the frustration of the rest of the group. The good news is that there are just a handful of things you need to do to run a productive and fun brainstorming session.

The overall goal of any brainstorming is to generate a high quantity of ideas. This is really important … **it's all about quantity, NOT quality**. You will have plenty of opportunity after brainstorming to evaluate the quality of the ideas generated and select a winner.

So if our goal is quantity, what strategies can we employ to accomplish this? Well, we want to eliminate as many barriers to idea flow as we can. **The two main barriers to idea flow are stress/tension and the left-brain's need to constantly evaluate things**. When you are stressed, it is very difficult to think about anything else other than that feeling of stress and maybe what is causing it. Therefore, our strategy is to be relaxed and to conduct the brainstorming at such a fast pace, that the left-brain doesn't have time to interrupt our flow.

When brainstorming, the process is broken up into three parts:

- Setting the Stage
- Idea Generation
- Evaluating the Ideas (only if there is time)

SETTING THE STAGE

This is when you communicate the objectives, set the tone for the brainstorming, and instruct everyone on how it will be run.

Make the objective Clear

Ensure that everyone in the room clearly understands what the purpose of the brainstorming is. What is the issue that you are all generating ideas for? Write it down as a title at the top of the whiteboard or computer screen.

Setting the Tone

Like I mentioned before, you want the meeting to be **relaxed and light-hearted**, but at the same time its purpose should be very clear.

It's your facial expressions, body language, and tone that will have the biggest effect over how relaxed the team will be going into the brainstorming session.

Prior to the meeting, do those things that relax you and put you into a great mood. It could be avoiding that extra cup of coffee, waiting until later to read that upset email from a customer, or reading Dilbert. Figure out what works for you and do it. You should also anticipate that the session will be fun and productive. This"positive visualization" technique used by athletes is very applicable here.

Smile. If you are already relaxed this won't be hard, and you certainly don't want to force one. If you smile when explaining how this session will be run, everyone will be more relaxed about it.

This may or may not work for you, but I used to keep a box of toys which I would bring with me to every brainstorming session. It would contain colorful and simple physical puzzles. The idea was that toys automatically set a more light-hearted tone in the room. They also gave people something to fiddle with and didn't require any of their real mental capacity, which I wanted them to save for idea generation.

Brainstorming Instructions

No matter if this is the first, second, tenth, or hundredth session you have had with this group, always start by reviewing the ground rules for the session. It helps to establish the pace you are after, and it minimizes the chances of anyone being offended by any actions during the session.

These are the instructions you should provide the team before brainstorming begins.

- Our goal is to fill this [screen | whiteboard | paper] with as many ideas as possible.
- The faster we can generate ideas, the better. Let them flow!
- Any and every idea is welcome, including the crazy ones
- Don’t provide any negative or positive critique of any idea.
- Mis-spelled words are ok. Don’t break our rhythm to provide spelling corrections.
- The wrong organization of ideas is ok. When the ideas are captured in an outline or mind map, it is ok if ideas go in the wrong place. That can be fixed later.
- No one idea will be discussed longer than 10 seconds. Anything that requires more will be listed on the “Discussion List”. The team will return to items on this list when idea generation is done. We do this because we want to maintain momentum.
- Interruptions are ok, and even encouraged, so speak up.
- And HAVE FUN!

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<http://www.innovationexcellence.com/blog/2012/03/23/brainstorming-fast-fun/#sthash.9PsYwipp.dpuf>

Okay, now for the next thinking technique: Analogical thinking.

Analogical Thinking

Analogical thinking can help you find a creative solution to a problem you're facing, by using knowledge you already have about similar problems and their solutions.

There are **three basic steps** that help you use analogical thinking. Here's an example to teach you the three steps:

Suppose you work for a packaging design firm, and you find out that grocery shoppers commonly complain that they often buy more groceries than they can fit in the reusable grocery bags that they take in the store. From this situation, you are given the following specific design problem:

> You need to design a new kind of reusable grocery bag that will stretch to fit more groceries inside it.

Now, here are the **three basic steps** for analogical thinking that will help you solve the problem:

STEP 1) Define the problem in general (abstract) terms.

A more general statement of this problem might be something like this:

> You need to design a new kind of container that can change to fit more items inside it.

STEP 2) Search your memory to find other problems that fit this general description

For instance, you might remember an example like this:

You once saw a TV show about a certain bird that carries seeds around in its mouth. But sometimes, the bird wants to carry more seeds than it can fit in its mouth. This kind of bird has an extendable pouch in its mouth that allows it to store many more seeds than its mouth could hold otherwise. The pouch wall is thin, wrinkled, and elastic, and stretches as seeds are added. This example fits the general problem description, because the bird's extendable pouch is a "container that can change to fit more items inside it".

STEP 3) See if you can use the solution to this other problem to generate ideas for solving your current problem, by drawing an analogy.

So, if we compare the grocery bag design situation to the bird example, we can make a diagram to help us draw an analogy between the two. See if you can draw the analogy by filling in the blank rectangle spaces on the right side of the diagram below (the first rectangle is filled in for you). Also, see if drawing this analogy helps you think of a solution for the grocery bag problem:

Bird Example	**Grocery bag problem**
[Birds] carry [seeds] in their [mouths]	[Shoppers] carry [ ] in their [ ]
But sometimes, [birds] want to carry more [seeds] than their [mouths] will hold.	But sometimes, [ ] want to carry more [ ] than their [ ] will hold.
The solution is an [extendable pouch]	One solution is an [ ]
built into the [bird's] [mouth]	built into the [ ] [ ]

After drawing this analogy, you could try to think of another example that fits the general problem definition, and draw another analogy between it and the grocery bag problem. You can basically keep doing this to help generate lots of creative solutions.

We would like you to use these ideas about brainstorming and about analogical thinking today to help solve the creative problem we give you.

[NOTICE: THIS MANIPULATION EXAMPLE PAIRS THE ANALOGICAL REASONING READING WITH BRAINSTORMING BLOG NUMBER ONE. BRAINSTORMING BLOG NUMBER TWO WAS ALSO USED WITH THE ANALOGICAL REASONING READING, BUT THAT COMBINATION IS OMITTED HERE TO SAVE SPACE]

(MANIPULATION: 3.a.iv: INTERACTING GROUP/ANALOGICAL REASONING CONDITION)

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Thinking about problems in an abstract way

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<u>**We would like you to use these ideas about thinking of problems abstractly and about analogical thinking today to help solve the creative problem we give you.**</u>

(MANIPULATION: 3.b.i: NOMINAL GROUP/BRAINSTORMING CONDITIONS)

Today, you are going to think of creative solutions to a problem.

Before you get your problem, we want you to read a couple of internet blog entries that discuss *brainstorming* – a technique for generating ideas.

[BRAINSTORMING BLOG NUMBER ONE]
Brainstorming…Fast and Fun!

How many times have you come out of a brainstorming session feeling unsatisfied with the results? The team never felt like it got into a rhythm. The idea flow felt like a drizzle versus a storm. None of the ideas that the team spent much time on seemed especially good (BTW, you should never spend a lot of time on any one idea in a brainstorming session). There was one or two people that insisted on dominating the conversation and ended up speaking way too much. This to the frustration of the rest of the group. The good news is that there are just a handful of things you need to do to run a productive and fun brainstorming session.

The overall goal of any brainstorming is to generate a high quantity of ideas. This is really important … **it's all about quantity, NOT quality**. You will have plenty of opportunity after brainstorming to evaluate the quality of the ideas generated and select a winner.

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When brainstorming, the process is broken up into three parts:

- Setting the Stage
- Idea Generation
- Evaluating the Ideas (only if there is time)

SETTING THE STAGE

This is when you communicate the objectives, set the tone for the brainstorming, and instruct everyone on how it will be run.

Make the objective Clear

Ensure that everyone in the room clearly understands what the purpose of the brainstorming is. What is the issue that you are all generating ideas for? Write it down as a title at the top of the whiteboard or computer screen.

Setting the Tone

Like I mentioned before, you want the meeting to be **relaxed and light-hearted**, but at the same time its purpose should be very clear.

It's your facial expressions, body language, and tone that will have the biggest effect over how relaxed the team will be going into the brainstorming session.

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Brainstorming Instructions

No matter if this is the first, second, tenth, or hundredth session you have had with this group, always start by reviewing the ground rules for the session. It helps to establish the pace you are after, and it minimizes the chances of anyone being offended by any actions during the session.

These are the instructions you should provide the team before brainstorming begins.

- Our goal is to fill this [screen | whiteboard | paper] with as many ideas as possible.
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- Interruptions are ok, and even encouraged, so speak up.
- And HAVE FUN!

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WRAPPING UP THE SESSION

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SUMMARY

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[BRAINSTORMING BLOG NUMBER TWO]
6 Tips for More Productive Brainstorming Sessions

You're sitting down with people throwing ideas around. You're writing stuff down more than usual. You're keeping an eye out for a standout idea that you can roll with. You're storming that brain. You're brainstorming.

The generation of ideas, to any team, is no doubt important. For example, at Design

Instruct, we meet and talk about future projects, we throw around ideas about artists we like and the work they do, we attempt to come up with fresh content ideas and new site features, and so on. Brainstorming is an important part of what we do.

Throughout the course of working closely together, we've discovered a few tips and tricks that often lead to great ideas after a brainstorming session. We thought we'd share some of them with you.

1. Create a Positive Atmosphere for Your Brainstorming Session
It's easy to think of meetings as boring, dreadful, painful and anxiety-inducing periods of time. Oftentimes, as a meeting participant or facilitator, you wish you could be doing something else. Sometimes people get called out, put on the spot, and fingers get pointed. Meetings are frequently perceived to be boring because they're repetitive and drudgingly systematic.

If you want to conduct an effective brainstorming session, it's important that the atmosphere is fun, positive, welcoming and judgment-free. This way, the meeting participants won't hesitate to share their ideas for fear of ridicule or reprimand from their peers.

2. Lay Out the Ground Rules
Clarity. It's sort of become a buzzword around the office for us. Clarity is a virtue. It's the starting point for most of what we do.

It's often said that there are no bad ideas in brainstorming. This is true. But there are ideas that just waste time and produce no actionable outcomes at all. These are the "ideas" that people throw out there to be funny or to add levity with no real substance.

Remember this: Respect the process of generating ideas. Otherwise, you're just wasting everyone's time.

You have to keep brainstorming focused. Do this by clarifying the objectives and the goals of a new project, and have everyone start from that point of clarity.

If what we're trying to achieve is clear, then every idea born out of a brainstorming session also inherits that same clarity.

At the end of your brainstorming session, you'll be left with a few really good ideas, and the only decision you need to make is to pick out the best ones to move forward with.

3. Don't Overlook Ideas that Aren't Everyone's Favorite
As long as an idea adheres to the objectives and the goals of the project, it should be

considered as a viable option.

At the very least, you should look at an idea as a jumping-off point for other ideas. Or you can take all these not-so-good ideas and synthesize them into one really good one; a sort of Frankenstein's monster of an idea.

4. Throw Away Ideas that Just Won't Work

Sometimes we get attached to ideas we come up with just by the mere fact that we came up with it. I do it all the time. I fall in love with an idea because I think it's clever or cool or I think it will be a hit, even if all indications point to the contrary.

However, again, be clear about what you need from the idea.

Not every idea you come up with will be a hit. That's impossible. In fact, I think most of you will agree that most ideas you come up with aren't going to be good. Therefore, you have to get rid of all of them. Throw them out there, put these ideas on the table and let them go. Let them float into the ether and be done with it. Those ideas were never yours to begin with. They're just vague abstractions: Notions that may have seemed good in your head, but with no real substance or no real chance of being successful.

The only time you can claim an idea as yours is when it's good enough for you to put it into action. That's the only time an idea actually starts to exist. It only becomes tangible and concrete when there's a chance of it being successful.

5. Don't Tune Out When Things Don't Go Your Way

Sometimes you won't agree with the direction the idea-generation process is taking. And if you're like me, your stubbornness and hardheadedness will tell you to just tune out, stop listening and stop contributing.

Fight the urge to shut off from the brainstorming session!

No good can come from shutting down. By not participating, you've just cut the team's efficacy by one person. That's one less brain, one less idea, and one less thoughtful insight.

Tuning out is not good for the brainstorming atmosphere. It isn't good for morale.

Try this instead: Voice out what's bothering you about the brainstorming session**.** It won't matter if you get angry or too impassioned with what bothers you. In fact, it might help the group better understand the pitfalls of the direction they're headed.

Think about it this way: If someone disagrees, it means that the idea in question isn't completely solid. There are still holes to be filled. The fact that you disagree is ultimately good for the outcome of the project.

6. Pragmatism First, Vision (Immediately) Second
Let’s face it: You need to achieve something with your ideas. That’s what brainstorming is for. You address some issues and you formulate solutions. It’s immediate. Your project is the task at hand. Therefore, you have to treat it as such.

Don’t let your idea get bigger than it needs to be right now.

Most creative people have great vision. Ideas will sometimes get out of hand, and they become these big, world-changing, life-defining things that get cumbersome and unwieldy when you do try to move them into action.

Some of the biggest ideas today started out very small and simple. However, if you study these ideas (e.g. Google’s search, Apple’s products, etc.) you’ll see that they started out from a place of clarity. They addressed specific needs and objectives. They were simple. Start there with your idea and let it grow.

Vision is important, but it can’t be the driving force behind the actual work and the time that needs to be put into getting an idea off the ground.

Vision is limitless for many people, and that’s never helpful when you have real, immediate objectives and needs for a project.

Vision merely guides an idea. Pragmatism is the thing that pushes it forward.

Share Your Own Brainstorming Session Tips!
- How does your company produce ideas in teams?
- In your experience, what strategies and techniques yield better and more productive brainstorming sessions?

Did you apply any of the tips mentioned above in your last brainstorming session?

See more at: <http://designinstruct.com/articles/project-management/tips-productive-brainstorming-sessions/>

We would like you to use these ideas about brainstorming today to help solve the creative problem we give you.

(MANIPULATION: 3.b.ii: NOMINAL GROUP/PROBLEM ABSTRACTION ONLY CONDITIONS)

Today, you are going to think of creative solutions to a problem.

Before you get your problem, we want to teach you some thinking techniques that we would like you to use. They involve using brainstorming techniques and thinking about problems in an abstract way.

Brainstorming…Fast and Fun!

How many times have you come out of a brainstorming session feeling unsatisfied with the results? The team never felt like it got into a rhythm. The idea flow felt like a drizzle versus a storm. None of the ideas that the team spent much time on seemed especially good (BTW, you should never spend a lot of time on any one idea in a brainstorming session). There was one or two people that insisted on dominating the conversation and ended up speaking way too much. This to the frustration of the rest of the group. The good news is that there are just a handful of things you need to do to run a productive and fun brainstorming session.

The overall goal of any brainstorming is to generate a high quantity of ideas. This is really important … **it's all about quantity, NOT quality**. You will have plenty of opportunity after brainstorming to evaluate the quality of the ideas generated and select a winner.

So if our goal is quantity, what strategies can we employ to accomplish this? Well, we want to eliminate as many barriers to idea flow as we can. **The two main barriers to idea flow are stress/tension and the left-brain's need to constantly evaluate things**. When you are stressed, it is very difficult to think about anything else other than that feeling of stress and maybe what is causing it. Therefore, our strategy is to be relaxed and to conduct the brainstorming at such a fast pace, that the left-brain doesn't have time to interrupt our flow.

When brainstorming, the process is broken up into three parts:

- Setting the Stage
- Idea Generation
- Evaluating the Ideas (only if there is time)

SETTING THE STAGE

This is when you communicate the objectives, set the tone for the brainstorming, and instruct everyone on how it will be run.

Make the objective Clear

Ensure that everyone in the room clearly understands what the purpose of the brainstorming is. What is the issue that you are all generating ideas for? Write it down as a title at the top of the whiteboard or computer screen.

Setting the Tone

Like I mentioned before, you want the meeting to be **relaxed and light-hearted**, but at the same time its purpose should be very clear.

It's your facial expressions, body language, and tone that will have the biggest effect over how relaxed the team will be going into the brainstorming session.

Prior to the meeting, do those things that relax you and put you into a great mood. It could be avoiding that extra cup of coffee, waiting until later to read that upset email from a customer, or reading Dilbert. Figure out what works for you and do it. You should also anticipate that the session will be fun and productive. This"positive visualization" technique used by athletes is very applicable here.

Smile. If you are already relaxed this won't be hard, and you certainly don't want to force one. If you smile when explaining how this session will be run, everyone will be more relaxed about it.

This may or may not work for you, but I used to keep a box of toys which I would bring with me to every brainstorming session. It would contain colorful and simple physical puzzles. The idea was that toys automatically set a more light-hearted tone in the room. They also gave people something to fiddle with and didn't require any of their real mental capacity, which I wanted them to save for idea generation.

Brainstorming Instructions

No matter if this is the first, second, tenth, or hundredth session you have had with this group, always start by reviewing the ground rules for the session. It helps to establish the pace you are after, and it minimizes the chances of anyone being offended by any actions during the session.

These are the instructions you should provide the team before brainstorming begins.

- Our goal is to fill this [screen | whiteboard | paper] with as many ideas as possible.
- The faster we can generate ideas, the better. Let them flow!
- Any and every idea is welcome, including the crazy ones
- Don't provide any negative or positive critique of any idea.
- Mis-spelled words are ok. Don't break our rhythm to provide spelling corrections.
- The wrong organization of ideas is ok. When the ideas are captured in an outline or mind map, it is ok if ideas go in the wrong place. That can be fixed later.
- No one idea will be discussed longer than 10 seconds. Anything that requires more will be listed on the "Discussion List". The team will return to items on this list when idea generation is done. We do this because we want to maintain momentum.
- Interruptions are ok, and even encouraged, so speak up.
- And HAVE FUN!

RUNNING THE ACTUAL BRAINSTORMING SESSION

Plan to capture the ideas in a way that is comfortable and fast for you, and visible to the entire team. You could use the whiteboard, a large pad of paper, or in Word or Excel (Pages or Numbers for us Mac folks). Whichever you use is fine, just make sure you are totally fast and comfortable. The last thing you want to do is slow down the team because you are struggling with the tool.

Say the first few ideas and capture them quickly. Prior to the meeting, try to have some ideas in your hip pocket. You will use them to **prime the pump**.

If no one else offers up any ideas right away, turn to the team with the best look of anticipation you can muster. If still nothing, quickly adding some additional ideas of your own. Do this a couple of times and the ideas should start coming.

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If you find yourself struggling to capture all the ideas because they are coming so fast …

Congratulations, you are running a fantastic brainstorming session! Let yourself smile in a big way and let the team see that. It's great positive reinforcement for everyone in the room.

WRAPPING UP THE SESSION

A really productive brainstorming session usually runs no more than 30 minutes. I wouldn't put a time constraint on it though. Just let it run out on its own. Once the team has decided that idea generation is done, return to those items that were put on the Discussion List. Let people finish expressing the thoughts that they had earlier. This could lead to a few more ideas being captured. Depending on the amount of time remaining, the team may want to identify which of the ideas are the best. You can do it together as a group or individually after the meeting is done.

But remember, that long list of ideas was the deliverable you were going after. Having it means that your brainstorming session was a success.

SUMMARY

The best way to run a productive brainstorming session is to make it fast and fun. You make it fun by getting yourself and the team into a relaxed state. And you make it fast so that your left-brain doesn't have time to stifle your right-brain's creativity.

And remember, to come up with a few high-quality ideas, you must first produce a high-quantity of ideas. So play the numbers game and generate lots of ideas during your brainstorming sessions.

Good luck, and have fun!

See more at:
<http://www.innovationexcellence.com/blog/2012/03/23/brainstorming-fast-fun/#sthash.9PsYwipp.dpuf>

Thinking about problems in an abstract way

In creative problem solving, it is often important to consider how you define the problem itself. Thinking of the problem in an abstract way can often help your group be creative. By abstract, we mean that you think very generally about the underlying problem situation, without focusing on specific details that are part of the problem.

For example, suppose you work for a packaging design firm, and you find out that grocery shoppers commonly complain that they often buy more groceries than they can fit in the reusable grocery bags that they take in the store. From this situation, you are given the following specific design problem:

> (Specific problem): You need to design a new kind of reusable grocery bag that will stretch to fit more groceries inside it.

Now, to think of this more abstractly, we can restate the problem by replacing specific words with more general words:

> (More abstract!): You need to design a new kind of shopping bag that will expand to fit more shopping items inside it.

Now, even more abstractly, we can write:

> (Even more abstract!): You need to design a new kind of container that can change to fit more items inside it.

Now, here's why this thinking technique helps: abstract problem statements sometimes remind you of other specific examples that fit the abstract statements. Those specific examples might give you some creative ideas about how to solve the actual problem you're working on.

We'd like you to practice this abstract technique so that we know you understand how to do it. Take the following specific problem and write it in an abstract form, and then in an even more abstract form:

> (Specific problem): You need to design a new kind of outdoor urban garden hose that stretches out and gets long when the cold water supply is turned on, but that also shortens and takes up very little space when the cold water supply is turned off.

> (More abstract! → finish this definition): You need to design a

> (Even more abstract! → finish this definition): You need to design a

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<u>We would like you to use these ideas about brainstorming and abstract problem definition techniques today to help solve the creative problem we give you.</u>

<u>[NOTICE: THIS MANIPULATION EXAMPLE PAIRS THE PROBLEM ABSTRACTION ONLY READING WITH BRAINSTORMING BLOG NUMBER ONE. BRAINSTORMING BLOG NUMBER TWO WAS USED WITH THE PROBLEM ABSTRACTION ONLY READING, BUT THAT COMBINATION IS OMITTED HERE TO SAVE SPACE]</u>

(MANIPULATION: 3.b.iii: NOMINAL GROUP/ANALOGY ONLY CONDITIONS)

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See more at:
<http://www.innovationexcellence.com/blog/2012/03/23/brainstorming-fast-fun/#sthash.9PsYwipp.dpuf>

Okay, now for the next thinking technique: Analogical thinking.

Analogical Thinking

Analogical thinking can help you find a creative solution to a problem you're facing, by using knowledge you already have about similar problems and their solutions.

There are **three basic steps** that help you use analogical thinking. Here's an example to teach you the three steps:

Suppose you work for a packaging design firm, and you find out that grocery shoppers commonly complain that they often buy more groceries than they can fit in the reusable grocery bags that they take in the store. From this situation, you are given the following specific design problem:

> You need to design a new kind of reusable grocery bag that will stretch to fit more groceries inside it.

Now, here are the **three basic steps** for analogical thinking that will help you solve the problem:

STEP 1) Define the problem in general (abstract) terms.

A more general statement of this problem might be something like this:

> You need to design a new kind of container that can change to fit more items inside it.

STEP 2) Search your memory to find other problems that fit this general description

For instance, you might remember an example like this:

You once saw a TV show about a certain bird that carries seeds around in its mouth. But sometimes, the bird wants to carry more seeds than it can fit in its mouth. This kind of bird has an extendable pouch in its mouth that allows it to store many more seeds than its mouth could hold otherwise. The pouch wall is thin, wrinkled, and elastic, and stretches as seeds are added. This example fits the general problem description, because the bird's extendable pouch is a "container that can change to fit more items inside it".

STEP 3) See if you can use the solution to this other problem to generate ideas for solving your current problem, by drawing an analogy.

So, if we compare the grocery bag design situation to the bird example, we can make a diagram to help us draw an analogy between the two. See if you can draw the analogy by <u>filling in the blank rectangle spaces</u> on the right side of the diagram below (the first rectangle is filled in for you). Also, see if drawing this analogy helps you think of a solution for the grocery bag problem:

Bird Example	**Grocery bag problem**
[Birds] carry [seeds] in their [mouths]	[Shoppers] carry [ ] in their [ ]
But sometimes, [birds] want to carry more [seeds] than their [mouths] will hold.	But sometimes, [ ] want to carry more [ ] than their [ ] will hold.
The solution is an [extendable pouch] built into the [bird's] [mouth]	One solution is an [ ] built into the [ ] [ ]

After drawing this analogy, you could try to think of another example that fits the general problem definition, and draw another analogy between it and the grocery bag problem. You can basically keep doing this to help generate lots of creative solutions.

<u>We would like you to use these ideas about brainstorming and about analogical thinking today to help solve the creative problem we give you.</u>

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Thinking about problems in an abstract way

In creative problem solving, it is often important to consider how you define the problem itself. Thinking of the problem in an abstract way can often help your group be creative. By abstract, we mean that you think very generally about the underlying problem situation, without focusing on specific details that are part of the problem.

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But sometimes, birds want to carry more seeds than their mouths will hold.	But sometimes, ______ want to carry more ______ than their ______ will hold.
The solution is an extendable pouch	One solution is an ______
built into the bird's mouth	built into the ______ ______

After drawing this analogy, you could try to think of another example that fits the general problem definition, and draw another analogy between it and the grocery bag problem. You can basically keep doing this to help generate lots of creative solutions.

<u>**We would like you to use these ideas about thinking of problems abstractly and about analogical thinking today to help solve the creative problem we give you.**</u>

APPENDIX B: RATER CALIBRATION

For all the ratings generated, solution ideas were judged by undergraduate raters, blind to hypotheses and experimental conditions. Due to the great number of ideas (over 3,600 ideas were generated by participants in this study), the ratings were performed in a multi-step procedure, similar to past creativity studies that evaluated large numbers of outputs (for an example, see Rietzschel et al., 2006). The procedure involved a pre-ratings "calibration" of the raters to each other to establish interrater similarity, and then a distribution of ideas among raters for assessment. I also included a post-ratings calibration check on interrater similarity that is typically not seen in studies with this number of rated outputs. The same multistep procedure was followed for ratings of novelty, usefulness, and overall creativity because these ratings were performed in parallel by each rater. I followed a somewhat similar calibration approach for flexibility ratings, but raters performed the categorization activities required for flexibility in an independent, earlier pass through the ideas. I describe the procedures below, and I present them in the temporal order in which they were performed.

Group idea flexibility. Two undergraduate RA raters, blind to this study's hypotheses, looked through approximately the first 50% of all solution ideas and generated 2 lists of independent problem solution category dimensions: solution means and solution goals (to review an earlier example of this methodology, see Nijstad et al., 2002). For example, a goal of many of the problem solutions was to prevent the taco shell from breaking; a common means that many solutions implemented was to add an extra taco shell. After 2 rounds of collaborative meetings, the RAs and I came up with a list of 24 means and 8 goals, which covered all the ideas we had looked through (refer to Table 2 for the goals and Table 3 for the means). Treating solution categories as unique combinations of means and goals, this procedure resulted in 192 unique idea categories. The next step was to use these categories to categorize every idea in the dataset.

Four undergraduate RA's then went through five groups' ideas from the pilot study and put each idea into 1 of the 192 categories. The pilot study used the same "fragile taco" task problem as the dissertation study. All the raters and I held two meetings in which discrepancies were discussed and resolved via collaboration. After these two meetings, each rater then independently went through another set of ten groups' ideas from the dissertation dataset and categorized the ideas. This served as the pre-ratings calibration dataset, and it contained 215 ideas. Because this was a categorization exercise with nominal variables, and not a ratings exercise with scales set up to measure variables in interval increments (e.g., like the novelty ratings), interrater agreement was assessed with a generalized version of Cohen's kappa which is suited to more than 2 raters (Cohen, 1960; Fleiss, 1971)[14].

I then randomly assigned each of the four undergraduate raters about a quarter of the remaining ideas in the dataset (about 850 ideas apiece), and they categorized their assigned ideas. The raters were unaware that I included a set of 50 ideas from the earlier calibration dataset, common to each rater's assignment, with the intent of checking their categorization agreement again. The 50 common ideas enabled the post-ratings calibration, and they were inserted at the end of each rater's assignment, so they would rate them last of all. I assessed interrater agreement again on this post-ratings calibration dataset by using the generalized Cohen's kappa coefficient.

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[14] See https://www.ibm.com/developerworks/community/files/app/folder/bbe88aaf-f3cd-466a-83fb-592d48eecb1c for a list of IBM developer software tools for SPSS, including the Fleiss kappa module used in this study.

The ratings activities for novelty, usefulness, and overall creativity occurred after the categorization ratings were performed. This meant that the raters had each seen a large number of ideas (1000+) before they embarked on the ratings for these variables.

Group idea novelty, usefulness, and overall creativity. I gave 3 raters 50 randomly selected ideas from the pilot study dataset, and they rated each solution idea using the 7 point Likert-type scales for novelty, usefulness, and overall creativity, as described in Chapter 4. I met with all the raters together and we discussed interrater disagreements of 2 points or more for each of the dependent variables, with the goal of reaching some consensus about how to rate ideas with the Likert-type scales across their entire range. After this meeting, I gave each of the raters an identical set of 158 randomly selected ideas from the dissertation idea dataset, and they independently rated the novelty, usefulness, and overall creativity of each solution idea.

For this pre-ratings calibration dataset, interrater reliability (IRR) and interrater agreement (IRA) were assessed using r_{wg} (for IRA) and ICC (for IRA + IRR) indices. Estimates of IRA and IRR are used to assess whether scores provided by judges are similar, although how similarity is conceptualized varies for IRA and IRR. Estimates of IRA indicate whether ratings furnished by multiple judges are interchangeable, i.e., whether they are equivalent in terms of their absolute value. Estimates of IRR are used to see whether raters rank order the targets of their ratings in a similar way. For this study, the ratings "targets" are the solution ideas. I wanted to know about both types of ratings similarity for the calibration dataset, because the remainder of the ideas would be divided up among the raters once they were calibrated to each other.

An estimate for r_{wg} was calculated for each set of ratings associated with a single idea. As a result, r_{wg} does not convey any direct information about ratings *across* ideas. In other words, information about interrater consistency in the rank order of ideas is not directly conveyed in the r_{wg} parameter estimate. In order to assess this aspect of ratings similarity, I used estimates of intra-class correlation.

Intra-class correlations (ICC) indicate the proportion of observed variance in ratings scores that are attributable to systematic between-target differences, as compared to the total variance observed (LeBreton & Senter, 2008; McGraw & Wong, 1996). Most of the intra-class correlations used to assess rater consistency are technically a function of both interrater agreement and interrater reliability (LeBreton & Senter, 2008). Because all the ideas in the calibration datasets were rated for novelty, usefulness, and overall creativity by the same 3 raters, and because I was not interested in generalizing beyond the 3 raters, a two-way mixed effects ANOVA served as the basis for the ICC estimate.

After seeing the results for IRA and IRR on the initial set of pre-ratings calibration ideas, I randomly distributed the remainder of the solution ideas from the dissertation study to the raters, to try to ensure rater and experimental condition were not confounded. The ideas were assigned and given out in several large subsets over a period of about 2 months.

I was concerned that the raters might drift away from their initially developed interrater consistency, so when I assigned the last big subset of ideas for rating, I included 50 of the original 158 calibration dataset ideas without mentioning it to the raters, as a post-ratings calibration dataset. My intent in assigning these ideas that they had already rated during the earlier calibration period was to check their IRA and IRR again at the end. This also enabled a true test-retest reliability analysis (Bobko, 2001), to see if any of the raters had drifted away from their own earlier ratings for the subset of 50 ideas. The test-retest reliabilities were calculated as the Pearson correlations between each raters' ratings of the 50 ideas common to the pre-ratings and post-ratings calibration datasets.

The proposed goal for this study was to have every idea rated by at least 2 raters, but the large number of solution ideas and the number of available raters made that goal unattainable in the time frame required to complete the ratings and the study. Other published studies have relied on creative output ratings provided by single raters, after using a second rater to assess IRA and/or IRR for some small proportion of output (typically 5-15% of the total). However, I have seen no such published creativity studies where IRA and IRR were checked *again* at the end of the ratings activity, and I have never seen a test-retest reliability analysis in studies like these. I included these extra steps as precautions so that rater drift could be measured and so that the quality of the ratings could be more accurately assessed. In the absence of these checks, the quality of measurement may diminish undetected.

I used the same pre-ratings calibration and post-ratings calibration check procedure for novelty, usefulness, and overall creativity. In fact, the same pre-ratings and post-ratings calibration idea sets were used in the process for all 3 ratings variables, i.e., the ratings for usefulness and overall creativity were performed in parallel with the novelty ratings.

Excerpts used to define novelty, usefulness, and overall creativity

In a meeting with all the raters, I used excerpts from Amabile (1996) to help establish conceptual definitions of novelty, usefulness, and overall creativity. Several pages were photocopied and taken to the meeting, and certain passages were highlighted and discussed during the meeting. No explicit guidance about how ratings of novelty and usefulness should combine to form overall creativity was discussed (although this question was asked), in keeping with guidance from the literature (e.g., Amabile, 1996). The highlighted excerpts appear below.

> The theoretical framework of creativity presented in the following chapter is based on a conceptual definition of creativity that comprises two esssential elements:
>
> > A product or response will be judged as creative to the extent that (a) it is both a novel and appropriate, useful, correct or valuable response to the task at hand, and (b) the task is heuristic rather than algorithmic.
>
> Barron (1955) proposed that, to be judged as "original," (1) the response "should have a certain stated uncommonness in the particular group being studied" and (2) it must be "to some extent adaptive to reality" (pp. 478-479). In other words, the incidence of the response must be statistically uncommon, and the response must be in some way appropriate to the problem.
>
> …virtually all conceptual definitions of creativity include notions such as value or appropriateness in addition to novelty.

APPENDIX C: MEASUREMENT VARIABLES

Team Cohesion

(adapted for this study from Seashore, 1954)
Completed by team members post-task

Seven point Likert-type scale: strong disagreement to strong agreement

Item wording	SPSS variable name
Our group got along together well.	COH1
Our members were willing to help each other.	COH2
Our group really stuck together.	COH3
I felt I was really a part of the group.	COH4

The original Seashore (1954) items:

Q51: Do you feel that you are really a part of your work group?

- □ Really a part of my work group
- □ Included in most ways
- □ Included in some ways, but not in others
- □ Don’t feel I really belong
- □ Don’t work with any one group of people

Q52: If you had a chance to do the same kind of work for the same pay, in another work group, how would you feel about moving?

- □ Would want very much to move
- □ Would rather move than stay where I am
- □ Would make no difference to me
- □ Would rather stay where I am than move
- □ Would want very much to stay where I am

Q50: How does your work group compare with other work groups at Midwest on each of the following points?

	Better than most	About the same as most	Not as good as most
The way men get along together	☐	☐	☐
The way the men stick together	☐	☐	☐
The way the men help each other on the job	☐	☐	☐

NOTICE: Q50 is really 3 different items; ∴ total Seashore items = 5. Adapted items for this study derived from Q50 and Q51.

Individualism/Collectivism

(Wagner III, 1995)
Completed by members post-task

Seven point Likert-type scale: strong disagreement to strong agreement

Item wording	**SPSS variable name**
Only those who depend on themselves get ahead in life.	INDCOL1
In the long run the only person you can count on is yourself.	INDCOL2
To be superior a person must stand alone.	INDCOL3
A group is more productive when its members do what they want to do rather than what the group wants them to do.	INDCOL4
A group is most efficient when its members do what they think is best rather than doing what the group wants them to do.	INDCOL5
A group is more productive when its members follow their own interest and concerns.	INDCOL6

Psychological Safety

(adapted for this study from Edmondson, 1999)
Completed by team members post-task

Seven point Likert scale: Strong Disagreement to Strong Agreement

Item wording	**SPSS variable name**
It was difficult to ask for help from my teammates during the task activity.	PSAFE1R
I felt safe to take risks during the task.	PSAFE2
We valued each others' unique knowledge and thinking skills during the task.	PSAFE3

The original items from Edmondson (1954)

1. If you make a mistake on this team, it is often held against you.
2. Members of this team are able to bring up problems and tough issues.
3. People on this team sometimes reject others for being different.
4. It is safe to take a risk on this team.
5. It is difficult to ask other members of this team for help.
6. No one on this team would deliberately act in a way that undermines my efforts.
7. Working with members of this team, my unique skills and talents are valued and utilized.

Divergent Task Conflict

(adapted from L. Weingart personal communication with K. Lewis)

Completed by team members post-task

Seven point Likert scale: Strongly disagree to Strongly agree

Item wording	SPSS variable name
We often engaged in debate about our different opinions and ideas.	DTCL1
We frequently debated the plusses and minuses of different ideas.	DTCL2
We often deliberated about one another's alternative viewpoints during our task discussion.	DTCL3

PANAS

(Watson & Clark, 1994)
Completed by members post-task

(Prompt)
The following are a number of words and phrases that describe different feelings and emotions. Read each item and write the appropriate number in the space next to that word. Think back to your interactions with your teammates today and indicate to what extent you felt this way, <u>while working with your teammate</u>.

Five point Likert scale: 1 = Very slightly or Not at all, 2 = A little, 3 = Moderately, 4 = Quite a bit, 5 = Extremely

	SPSS variable name			**SPSS variable name**
Interested[*]	PAN_INT		Irritable[**]	PAN_IRR
Distressed[**]	PAN_DIS		Alert[*]	PAN_ALE
Upset[**]	PAN_UPS		Ashamed[**]	PAN_ASH
Excited[*]	PAN_EXC		Inspired[*]	PAN_ISP
Strong[*]	PAN_STR		Nervous[**]	PAN_NER
Guilty[**]	PAN_GUI		Determined[*]	PAN_DET
Scared[**]	PAN_SCR		Attentive[*]	PAN_ATT
Hostile[**]	PAN_HOS		Jittery[**]	PAN_JIT
Enthusiastic[*]	PAN_ENT		Active[*]	PAN_ACT
Proud[*]	PAN_PRO		Afraid[**]	PAN_AFR

[*] indicates positive affect item; [**] indicates negative affect item

Personality: Big Five short scale

(Gosling et al, 2003)
Completed by team members post-task

Scale as shown in table below

Here are a number of personality traits that may or may not apply to you. Please write a number next to each statement to indicate the extent to which *you agree or disagree with that statement*. You should rate the extent to which the pair of traits applies to you, even if one characteristic applies more strongly than the other.

Disagree strongly	Disagree moderately	Disagree a little	Neither agree nor disagree	Agree a little	Agree moderately	Agree strongly	
1	2	3	4	5	6	7	[SPSS variable name]

I see myself as:

1.	_____	Extraverted, enthusiastic	[B5EXT1]
2.	_____	Critical, quarrelsome	[B5AGR1R]
3.	_____	Dependable, self-disciplined	[B5CON1]
4.	_____	Anxious, easily upset	[B5EMO1R]
5.	_____	Open to new experiences, complex	[B5OPN1]
6.	_____	Reserved, quiet	[B5EXT2R]
7.	_____	Sympathetic, warm	[B5AGR2]
8.	_____	Disorganized, careless	[B5CON2R]
9.	_____	Calm, emotionally stable	[B5EMO2]
10.	_____	Conventional, uncreative	[B5OPN2R]

TIPI scale scoring: Extraversion: 1, 6R; Agreeableness: 2R, 7; Conscientiousness: 3, 8R; Emotional Stability: 4R, 9; Openness to Experience: 5, 10R.

Transactive Memory Systems: Specialization

(adapted from Lewis, 2003)
Completed by team members post-task

Five point Likert scale: strong disagreement to strong agreement

1. Each team member has specialized knowledge of some aspect of our creativity task.
2. Different team members are responsible for expertise in different areas.
3. I have knowledge about an aspect of the creativity task that no other team member has.
4. I know which team members have expertise in specific areas.
5. The specialized knowledge of several different team members is needed to complete the creativity task.

The original TMS: Specialization items from Lewis (2003)

1. Each team member has specialized knowledge of some aspect of our project.
2. I have knowledge about an aspect of the project that no other team member has.
3. Different team members are responsible for expertise in different areas.
4. The specialized knowledge of several different team members is needed to complete the project deliverables.
5. I know which team members have expertise in specific areas.

Transactive Memory Systems: Credibility

(adapted from Lewis, 2003)
Completed by team members post-task

Five point Likert scale: strong disagreement to strong agreement

1. I was comfortable accepting procedural suggestions from other team members.
2. I trusted that other members' knowledge about the creativity task was credible.
3. I was confident relying on the information that other team members brought to the discussion.
4. When other members gave information, I didn't feel the need to double-check it for myself.
5. I had a lot of faith in other members' "expertise."

The original TMS: Credibility items from Lewis (1999)

1. I was comfortable accepting procedural suggestions from other team members.
2. I trusted that other members' knowledge about the project was credible.
3. I was confident relying on the information that other team members brought to the discussion.
4. When other members gave information, I wanted to double-check it for myself. (reversed)*
5. I did not have much faith in other members' "expertise." (reversed)*

*Lewis (2003) recommends <u>not</u> using the reversed wording for these items

Transactive Memory Systems: Coordination

(adapted from Lewis, 2003)
Completed by team members post-task

Five point Likert scale: strong disagreement to strong agreement

1. Our team worked together in a well-coordinated fashion.
2. Our team had very few misunderstandings about what to do.
3. Our team didn't need to backtrack and start over a lot.
4. We accomplished the creativity task smoothly and efficiently.
5. There was little confusion about how we would accomplish the creativity task.

The original TMS: Coordination items from Lewis (2003)

1. Our team worked together in a well-coordinated fashion.
2. Our team had very few misunderstandings about what to do.
3. Our team needed to backtrack and start over a lot. (reversed)*
4. We accomplished the task smoothly and efficiently.
5. There was much confusion about how we would accomplish the task. (reversed)*

*Lewis (2003) recommends <u>not</u> using the reversed wording for these items

Demographic and Control Variables

Completed by students after task
No talking was allowed

ITEM:
1. Which team member are you? (circle one) Red White Blue

SPSS Variable name: DEM_COLOR

ITEM:
2. Your age _______

SPSS Variable name: AGE

ITEM:
3. Gender M F

SPSS Variable name: SEX

ITEM:
4. Class status: Freshman Sophomore Junior Senior Other

SPSS Variable name: DEM_CLASS

ITEM:
5. Major in school: ____

SPSS Variable name: MAJOR

ITEM:
6. How many YEARS of full-time (>35 hours per week) work experience do you have? ___

SPSS Variable name: FTEXP

7. How many YEARS of part-time (<35 hours per week) work experience do you have? ___

SPSS Variable name: PTEXP

ITEM:
8. Is English your native language? Y N

SPSS Variable name: ENGLFIRST

ITEM:
If NO, what is your native language? ________________________________

SPSS Variable name: NATLANG

ITEM:
9. Ethnicity/Race (optional):

- ___ Hispanic
- ___ American Indian or Alaska Native
- ___ Asian
- ___ Black or African American
- ___ Native Hawaiian or Other Pacific Islander
- ___ White, non-Hispanic

SPSS Variable name: ETHN

ITEM:
10. To what extent did you know your other team members **before** the study today?

[1 = did not know at all; 2 = knew slightly; 3 = knew well; 4 = knew very well]

Familiarity with other member (COLOR):	1	2	3	4
Familiarity with other member (COLOR):	1	2	3	4

SPSS Variable name: FAM_1; FAM_2

ITEM:
11. Can you guess what we are testing in this study?

(free response)

THE RESPONSES TO THIS ITEM WERE NOT PUT INTO THE SAS OR SPSS DATABASE. FROM READING THROUGH ALL THE RESPONSES, ALMOST NOBODY GUESSED THAT WE WERE INTERESTED IN GROUP COGNITION, NONE GUESSED WE WERE INTERESTED IN THE UNDERSTANDING THEY HAD OF OTHERS' MENTAL MODEL CONTENTS, AND NOBODY GUESSED THE EXACT HYPOTHESES

ITEM:
12. Have you taken any product design or functional modeling classes before today?

(circle one) Y N

SPSS Variable name: PREVDES

ITEM:
If YES, what was the class? ___________________________________

SPSS Variable name: DES_CLASS

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