Team Performance on a Computerized Intellective Task

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LOYOLA UNIVERSITY CHICAGO

TEAM PERFORMANCE ON A COMPUTERIZED INTELLECTIVE TASK

A THESIS SUBMITTED TO

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BY

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ABSTRACT

This study examined the effects of a reflexivity manipulation on the performance of dyads and triads working on an intellective task known as letters-to-numbers. Past research has shown triads consistently outperforming dyads on this task. The current study sought to determine whether giving dyads an opportunity to reflect on strategy would close this gap in performance. Participants performed a computerized version of two letters-to-numbers problems in dyads or triads. Between problems, half of the groups performed a reflexivity task designed to facilitate strategy improvements. Experimental sessions were videotaped. It was predicted that triads would outperform dyads, reflexivity groups would outperform control groups, and that this improvement would be greater for dyads than for triads. Results contradicted expectations. Triads in the reflexivity condition performed worse than those in the control condition. The performance of dyads did not differ between conditions. Limitations of the study and recommendations for future research are discussed.
CHAPTER ONE
LITERATURE REVIEW

Whenever people are confronted with a problem to be solved, one strategy they often pursue is to work with, or at least consult, other people. The concept of “two heads is better than one,” or that groups are inherently superior to individuals when approaching a problem, persists as a traditional problem-solving maxim for its apparent simplicity and utility. However, the scientific research community has questioned both the seemingly simple nature of group problem solving, as well as how advantageous it actually is to work in groups.

Group activities can vary in many ways, resulting in distinctly different types of tasks. Various systems of organizing these tasks have been proposed. One such system, described by Laughlin (1980), organizes group tasks along a continuum ranging from “intellective” to “judgmental.” Intellective tasks have a demonstrably and objectively correct solution, while solutions to judgmental task are subjective. An example of an intellective task is a mathematical problem \((3x + 1 = 7, x = ?)\), while an example of a judgmental task is deciding which of two pieces of abstract artwork is better. There is no arguing with the fact that \(2 + 2 = 4\), assuming one can follow the rules of arithmetic. This concept can also be demonstrated to an audience; one can prove that the answer is correct, and so it is considered demonstrable. In a description of the intellective–judgmental continuum for group tasks, Laughlin & Ellis (1986) list four criteria that must
be met for a task to be classified as demonstrable: (1) the group must agree on the conceptual system that is to be applied, (2) the group must possess sufficient information to complete the task, (3) group members who are unable to solve the problem themselves must nevertheless be able to recognize a correct solution if it is presented to them, and (4) group members who can solve the problem themselves must have sufficient ability, motivation, and time to demonstrate the correct solution to others in the group.

**Group versus Individual Problem-Solving**

In previous research, groups have been shown to consistently outperform average individuals on a variety of problem-solving tasks (Baron, Kerr, & Miller, 1992; Brown, 2000; Davis, 1969; Davis, 1992; Forsyth, 1999; Hackman & Morris, 1975; Hastie, 1986; Hill, 1982; Hinsz, Tindale, & Vollrath, 1997; Kelley & Thibaut, 1969; Kerr, MacCoun, & Kramer, 1996a, 1996b; Levine & Moreland, 1998; Lorge, Fox, Davitz, & Brenner, 1958; McGrath, 1984; Stasser & Dietz-Uhler, 2001; Steiner, 1972). It is important to note however that although groups consistently outperform average individuals, but have seldom been shown to outperform the best individuals on problem-solving tasks. An exception is a series of studies on the letters-to-numbers task (Laughlin, Bonner, & Miner, 2002; Laughlin, Zander, Knievel, & Tan, 2003; Laughlin, Hatch, Silver, & Boh, 2006). On letters-to-numbers tasks groups of three or more have been shown to outperform even the best individuals. Such results suggest that there may be something unique about the letters-to-numbers task (described in detail below) that warrants further investigation.
Letters-to-Numbers

The letters-to-numbers task is a cryptographic task that requires participants to solve a coding of the numbers 0-9 randomly assigned to letters A-J, with no repetitions. The objective is to solve the full mapping of letters to numbers. To achieve this goal, participants propose mathematical equations in letters, and receive solutions to those equations in letters. An example of an equation that might be proposed by a participant is “A + B – D = ?” which might elicit the feedback that “A + B – D = EI.” It is important to note that two-letter expressions indicate two-digit numbers, not the multiplication of two numbers as is normally the case with an algebraic expression. Thus, EI is a single two-digit number. Proposed equations may use only addition and subtraction as mathematical operations. The task is grouped into “trials,” with each trial consisting of (a) a proposed equation, (b) a solution to that equation provided by the experimenter, (c) participants’ guessing the values of any of the letters they wish, and (d) feedback about whether or not those guesses are correct. For example, using the previous equation, a participant might guess that A = 8 and E = 1, and be told that A = 8 is incorrect but that E = 1 is correct. Once the participant knows that E = 1, a useful follow-up equation would be “E + E = ?” which will identify the letter code for the number 2. The letters-to-numbers problem is solved successfully upon correctly identifying all letter values. Performance is measured by the number of trials participants take to solve the problem. Participants attempt to solve the problem in as few trials as possible.

The letters-to-numbers task is an intellective, or demonstrable, task due to its mathematical and logical nature (Laughlin, 1980). The problem involves intermediate steps/solutions (solving for individual letters) that eventually lead to a solution of the full
mapping of letters-to-numbers. For example, if a participant learns that “A + B – D = E1,”
a logical assumption is that E = 1, since the addition of any two numbers in the 0-9 range
can never be greater than 17.

The initial letters-to-numbers study (Laughlin et al., 2002) tested the performance
of individuals versus four-person interacting groups on the letters-to-numbers task. The
groups outperformed even the best individuals in comparably sized nominal groups—an
extremely rare result in problem-solving research. Interacting groups used fewer trials to
solution, and proposed and identified more letters per equation. The superior performance
of groups was attributed by Laughlin et al. (2002) to the highly intellective nature of the
letters-to-numbers task (see also Larson, 2010; Laughlin, 2011).

Subsequent studies further explored this phenomenon. Laughlin et al. (2003) used
the same letters-to-numbers task, but compared the performance of individuals to three-
person groups and had all participants perform the task twice. An additional experimental
manipulation was included in which participants were given one of five different sets of
instructions for performing the task. While one of these was the standard instructions
used in Laughlin et al. (2002), the other four provided additional information to
participants. Two of these revealed the coded letter corresponding to one of the numbers
(either 1 or 9) at the beginning of the task. The other two conditions forced participants to
use at least three or at least four letters per equation while they performed the task. The
purpose of the latter manipulation was to encourage them to use more complex equations.
The performance for groups in the different instructions conditions were ordered as
follows, in order of best to worst performance: Number 9 known > At least 4-letter
Groups again outperformed individuals (used fewer trials to solution).

A third study (Laughlin et al., 2006) addressed the effect of group size on letters-to-numbers task performance. The task was administered twice to individuals as well as to group of two, three, four, and five members. The results demonstrated that groups of three or more persons generally require fewer trials than even the best of a comparable number of individuals working alone to solve the letters-to-numbers problem (Laughlin et al., 2002; Laughlin et al., 2003). Interestingly, Laughlin et al. (2006) found that the performance of dyads was significantly poorer than that of larger groups, and was not different from that of individuals. Furthermore, while the performance of group of size three, four, and five were all better than that of dyads, they were not significantly different from one another. These results suggest that groups with three members are sufficiently large to improve performance relative to individuals and dyads, but the addition of more people to those groups does not increase performance any further. This pattern of results has not been fully explained by any research to date.

The results of previous letters-to-numbers studies seem to indicate something unique about the letters-to-numbers task itself. Letters-to-numbers problems can be viewed as consisting of two separate and distinct subtasks: strategy development and strategy implementation (Larson, 2010). Group performance on complex tasks depends partially on the group’s ability to perform both strategy subtasks (Hackman, 2002; Hackman & Wageman, 2005; Marks, Mathieu, & Zaccaro, 2001; Salas, Sims, & Burke, 2005). Strategy development is the planning of how to accomplish a task, including the selection, organization, and adaptation of ideas and actions (Marks et al., 2001; Salas et
al., 2005; Tschan, Semmer, Nägele, & Gurtner, 2000). With regard to letters-to-numbers, it is planning how to go about solving the decoding problem (e.g., whether to use complex or simple equations, whether to give wild guesses about letters or to confirm logically deduced letters, etc.), and might include as well consideration of the relative merits of different strategies. Strategy implementation, on the other hand, is the actual use of whatever strategy has been selected for accomplishing the task (Marks et al., 2001). Regarding the letters-to-numbers task, it means, for example, following through with creating equations of a chosen type, making certain kinds of guesses, etc. The letters-to-numbers task requires that both of these operations be performed simultaneously to achieve optimal performance. As such, Larson (2010) suggests that one possible explanation for the unique pattern of results from previous letters-to-numbers studies is the relative ability of groups of different sizes to perform the strategy development and implementation subtasks simultaneously. Specifically, the similar performance of individuals and dyads may indicate an inability on the part of dyads to perform both subtasks successfully, or at least no better than individuals. The presence of a third group member may be necessary and sufficient to add the cognitive resources required to implement one strategy while simultaneously hunting for and evaluating alternative strategies. Once groups can accomplish this, adding more people to the group (increasing group size past 3) may show no further improvement because the conditions for optimal group performance have already been met. The difference in performance between dyad (which do not perform better than the best individuals) and larger groups (which do perform better than the best individuals and better than dyads) may be explained by the prioritization of one subtask (strategy implementation) at the expense of the other.
strategy development). The letters-to-numbers problem simply cannot be solved at all without implementing some strategy (performing the task), regardless what that strategy is. However, further strategy development does not have to occur once an individual or group has selected a strategy that works, even if it is a poor (inefficient) one.

Individuals and dyads, lacking the cognitive resources to develop better strategies, may simply be forced to stick with whatever strategy they come up with initially, even if it is suboptimal. Larger groups, on the other hand, should be more capable of developing better strategies, even as they are executing their current strategy, and perform better as a result. For example, a relatively poor letters-to-numbers strategy would be to use simple two-letter equations ("A + B = ?", "C – F = ?", etc.); such equations represent a hit-or-miss approach that are limited in utility for solving the code (a two-letter equation might produce a useful two-digit answer that reveals the code for the number 1, or a much less useful one-digit answer which does not help to solve any part of the code). The results from previous letters-to-numbers studies confirm that group performance generally increases as groups use more letters in their equations (Laughlin et al., 2002; Laughlin et al., 2003; Laughlin et al., 2006). An individual might be aware of these limitations, but not have the time or energy to think about alternative equation methods, instead choosing to just “go with it” and try to solve the code as best they can using simple 2-letter equations. A more efficient equation strategy would be to add all of the coded letters together ("A + B + C + D + E + F + G + H + I + J = ?"), since the result of this equation will always be 45 (i.e., regardless of the code, it always contains the numbers 0-9, the sum of which equals 45). Using this equation will therefore give the participant(s) the letters representing the numerals 4 and 5 in the code, and eliminate the need for an
inefficient hit-or-miss approach such as the one discussed previously. This strategy can then be repeated, with the sum of the remaining unsolved letters always being equal to 36 (i.e., $45 - 4 - 5 = 36$), and so forth. This strategy can be arrived at by a logical consideration of the task, and is an improvement over a two-letter strategy. However, such logical reasoning processes may not be attractive (or possible) for strategy development purposes for individuals or groups too small to spare the cognitive resources necessary to perform it.

**Reflexivity: A Method for Improving Group Performance**

Various methods for improving group performance have been proposed. West (1996, 2000) introduced the idea that members of a group should “overtly reflect upon objectives, strategies, and processes relative to their assigned task,” and “adapt their ideas to current or anticipated circumstances.” However, groups do not seem to engage in this reflexivity or planning process automatically, or all of the time (Hackman, Brousseau, & Weiss, 1976; Weingart, 1992). One reason is that reflexivity may, under some circumstances, appear to require more effort than it is worth. To counter this, Gurtner, Tschan, Semmer, & Nägele (2007) introduced the idea of guided reflexivity interventions, based on a reflexivity process described in West (2000), as a method to ensure that groups engage in such processes. The process consists of three stages: (1) Groups reflect on how they have performed so far (to consider potential improvements), (2) Develop plans for implementing new strategies, and (3) actually implement those new strategies. Gurtner et al. (2007) had groups of participants perform a team task across two team meetings, with an intervention occurring at the beginning of the second meeting. Teams were randomly assigned to one of two reflexivity conditions (group or individual),
or to a control condition in which participants performed an unrelated task. In the group
reflexivity condition, participants were given a list of questions to answer and discuss
with their group. The individual reflexivity condition followed the same format, but
group members were separated from their group and performed the reflexivity task
independently. The instructions, which did not suggest specific strategies, followed the
reflexivity framework in West (2000), with groups first being directed to think about their
performance on the task thus far (e.g. “How did you ask for information from your
teammates? How did you pass on that information?”), then to consider potential
improvements to their performance (e.g. “Are there alternatives to your chosen task
performance procedures? If so, what are they?”), and finally to develop suggestions for
task improvement for future work. It was hypothesized that reflection on task strategies
would allow for adaptation (development) of strategies, and that this was an important
factor for improving performance.

Why does reflexivity work? Gurtner et al. (2007) considers reflexivity
interventions as a prompt for group members to evaluate the objectives of their group
task, as well as the group processes necessary to perform it. Taking time to think about
the task may allow groups to identify opportunities to improve the strategies they are
currently using. Making such improvements in strategy, and then implementing the better
strategies, may allow groups to perform better than they would have had they not
engaged in the reflection process. There have been several other studies demonstrating an
improvement in group performance as a result of reflexivity interventions (Carter &
West, 1998; De Dreu, 2002; Gevers, van Eerde, & Rutte, 2001; Schippers, Den Hartog,
but reflexivity interventions have not yet been applied to problem-solving groups.

**Reflexivity and Letters-to-Numbers Tasks**

Letters-to-numbers tasks can be viewed as having two subtasks: strategy development and strategy implementation. Groups performing the letters-to-numbers task may differ in their handling of the two subtasks; some may attempt to perform both simultaneously, others choose to focus on each separately, or still others may prioritize one subtask at the expense of the other. The necessity of strategy implementation and concomitant inability of smaller groups to simultaneously focus on strategy development may lead such groups to persist with suboptimal strategies, and so explain the differences in performance among groups of different sizes observed in previous letters-to-numbers studies. Those groups that are willing and able to undertake strategy development can use their improved strategies to better their performance relative to groups that do not perform strategy development, or do not do so adequately.

Previous research has highlighted the importance of groups developing and implementing good task performance strategies (Guzzo, Wagner, Maguire, Herr, & Lawley, 1986; Hackman, 2002). Reflexivity interventions have been shown to increase group performance by encouraging the development of improved task performance strategies. However, the benefit of reflexivity for groups has not been applied to problem-solving tasks. Reflection may be a means by which groups that previously employed suboptimal strategies can improve their strategies and perform up to the level of groups that, perhaps due to their size, can engage in reflection “on the fly” as they perform their task. That is, the benefits of reflexivity interventions may differ depending on the size of
the group. If groups with at least three members are already engaged in strategy
development processes naturally as they perform the letters-to-numbers task, then a
reflexivity intervention is apt to be redundant, and so will have little or no impact on their
performance. On the other hand, reflexivity interventions may lead to noticeable
performance improvements in dyads, which may lack the capacity to perform strategy
development on their own as they are working on a task. The critical difference between
the performance of dyads and triads, then, may be in their ability to develop new and
better strategies spontaneously while they are simultaneously implementing an existing
strategy. Reflexivity interventions for dyads offer a possible way to narrow this
performance gap.

**Study Design**

The current study attempted to test this idea. The letters-to-numbers problem was
administered to dyads and triads twice, with half of the dyads and triads receiving a
reflexivity intervention between the two administrations. The other half of the dyads and
triads were given an alternate activity to complete between the two administrations of the
letters-to-numbers problem. The groups were videotaped during the experiment sessions
so that discussions of strategy development could be coded later. Performance on the
letters-to-numbers problems was measured by the number of trials needed to complete
the task (as in previous letters-to-numbers studies), with fewer trials indicating better
performance. The following predictions were tested:

Hypothesis 1: There will be a main effect of group size, such that, collapsing
across reflexivity conditions, triads will outperform dyads on letters-to-numbers tasks.
Hypothesis 2: There will be a main effect of reflexivity, such that, collapsing across group sizes, groups in the reflexivity condition will outperform those in the control (no reflexivity) condition.

Hypothesis 3: Reflexivity and group size will interact, such that the benefits to performance of reflexivity will be stronger in dyads than triads.
CHAPTER TWO

METHOD

Participants

102 undergraduate students from introductory psychology classes at Loyola University Chicago participated in the study. Participants were randomly assigned to either triads or dyads, with 60 participants in 20 triads and 42 participants in 21 dyads. Students earned credit toward fulfilling a course requirement in exchange for participating in this study.

Experimental Task

Participant groups performed a version of the cryptographic task, letters-to-numbers (Laughlin et al., 2002; Laughlin et al., 2003; Laughlin et al., 2006), that was presented via computer. The numbers 0-9 were randomly coded as the letters A-J with no repetitions (e.g., A = 3, B = 0, C = 6, D = 8, E = 1, F = 2, G = 9, H = 4, I = 5, J = 7). The goal for participants was to figure out which numbers correspond with which letters, and to solve the code in as few trials as possible. Participants performed the task twice, with a different random coding each time.

To get hints about the code, participants proposed addition and subtraction equations using letters (e.g., A + B – D = ?). Each letter represents a digit, such that two-letter expressions (e.g., CF) represent two-digit numbers, and not the product of two numbers. Participants could use as many letters and operations per equation as they
wanted. Participants submitted equations one at a time, and received answers to those equations in letters (e.g., $A + B - D = EI$). After receiving the answer to an equation, participants had the opportunity to guess the values of any or all of the coded letters. The computer program provided feedback as to whether these guesses were correct or incorrect. Participants then entered a new equation to get another hint, followed by another opportunity to guess the coded values. The problem was solved when the full mapping of letters to numbers was guessed correctly. Participants were limited to 10 trials overall, after which the program terminated.

**Procedure**

When participants entered the laboratory they were first given an overview of the experimental session as part of the informed consent process. They were informed that they would be attempting to complete two letters-to-numbers problems as a group, with a break period in between, and they were also notified that the session would be videotaped. If after hearing this overview they still wished to participate, they were asked to sign the informed consent document.

The participants next heard a detailed verbal description of the letters-to-numbers task, and received complete instructions on how to perform the task using a computer. They also read a written summary of the task instructions on the computer screen before starting the first problem. Participants were informed that their task was to solve the coding of letters to numbers in as few trials as possible, where a trial consists of entering an equation, receiving an answer, guessing at values of the coded letters, and receiving feedback on those guesses. Participants were given a maximum of 10 trials to solve the problem, but no time limit. The program ended either when participants solved the code
or they reached 10 trials, at which point the group’s score was displayed (the number of trials participants used to complete the task). The experimenter sat quietly in the corner of the room while the participants performed the task. After being given the task instructions, participants worked as a group to complete the first letters-to-numbers problem.

After participants completed the first letters-to-numbers problem, the experimenter explained one of two different tasks that participant groups would complete next, depending on their experimental condition. Participants in both conditions were given verbal instructions, as well as a written summary of those instructions. Participants in the reflexivity condition were instructed to reflect upon their performance, while groups in the control condition discussed an unrelated topic (both described more fully below). In both conditions, groups had 5 minutes to perform the task while the experimenter waited outside the room.

Following the discussion period, the experimenter re-entered the room and explained to participants that they would be performing the letters-to-numbers problem again, this time with a different random coding to solve. Participants then completed the second letters-to-numbers problem. After completing the second letters-to-numbers problem, participants were thanked for their participation, debriefed, and dismissed. Experimental sessions were videotaped to allow for analysis of strategy-related discussions in the participant groups.

**Reflexivity Manipulation**

Half of the triad groups and half of the dyad groups performed a reflexivity task in between the two letters-to-numbers problems, while the other half of participants
performed a control task. The reflexivity task gave groups the opportunity to reflect on their performance on the first letters-to-numbers problem, develop plans to improve their performance on the second letters-to-numbers problem, and consider how to implement their new plans. However, participants were not given specific suggestions to improve their performance (see Appendix A). Groups were given 5 minutes to reflect before beginning the second letters-to-numbers problem. Groups in the control condition were given 5 minutes to discuss an unrelated topic (suggestions to improve their university) instead of having the opportunity to reflect on their performance (see Appendix B), and then began the second letters-to-numbers problem.

**Measures**

Group performance was measured as the number of trials required to solve the second letters-to-numbers problem, with fewer trials to solution indicating better performance. The number of trials groups used to solve the first letters-to-numbers problem was used as a covariate in the analysis.

Strategy-related group discussion by groups during the reflexivity task was measured as a manipulation check. Groups were videotaped and their discussion coded to allow for analysis of their behaviors. The coding scheme for the videos focused on identifying instances of participants discussing strategy ideas within the following categories: Explicit strategy (specific thoughts that can be directly implemented), Meta-strategy (general thoughts regarding strategy), and Strategy arguments for both Explicit strategies and Meta-strategies (opinions supporting or opposing previously suggested ideas). Additionally, any instances of newly developed Explicit Strategies being
implemented while solving the second letters-to-numbers problem (excluding ideas used during the first problem) were also noted (see Appendix C).
CHAPTER THREE

RESULTS

Manipulation Check

*Reflexivity Manipulation.* An independent samples *t*-test was conducted for each of the strategy behavior categories coded from the videotaped discussion periods during which groups discussed either the reflexivity or control task, depending on experimental condition. For all strategy behaviors, groups in the reflexivity condition discussed significantly more strategy concepts (and implemented more new strategy ideas) than groups in the control condition (Explicit Strategy, *t* (39) = 8.87, *p* < .001; Meta-strategy, *t* (39) = 4.74, *p* < .001; Explicit Strategy Arguments = 4.45, *p* < .001; Meta-strategy Arguments, *t* (39) = 2.65, *p* < .05; Implementation of new Explicit Strategies, *t* (39) = 2.75, *p* < .05). Mean frequencies and standard deviations for ideas discussed and implemented by reflexivity groups are presented in Table 1. Groups in the control condition discussed exactly zero strategy concepts. This suggests that the manipulation operated as expected.
Table 1. Mean frequencies and standard deviations for strategy behaviors observed in reflexivity groups during reflexivity period.

<table>
<thead>
<tr>
<th>Strategy Code</th>
<th>Mean Frequency</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explicit Strategies</td>
<td>3.00</td>
<td>1.55</td>
</tr>
<tr>
<td>Meta-strategies</td>
<td>0.95</td>
<td>0.92</td>
</tr>
<tr>
<td>Explicit Strategy Arguments</td>
<td>2.05</td>
<td>2.11</td>
</tr>
<tr>
<td>Meta-strategy Arguments</td>
<td>0.33</td>
<td>0.58</td>
</tr>
<tr>
<td>Implemented Explicit Strategies</td>
<td>0.52</td>
<td>0.87</td>
</tr>
</tbody>
</table>

**Letters-to-Numbers Performance**

I conducted two analyses to test hypotheses. The first is a 2 (Group Size: Dyad, Triad) x 2 (Reflexivity Condition: Reflexivity, Control) analysis of covariance (ANCOVA) on participant’s performance on the second letters-to-numbers problem, using their performance on the first letters-to-numbers problem as a covariate (see Figure 1). The second analysis, conducted to explore additional patterns in the data, is identical to the first, with the exception that the covariate was not included (see Figure 2). However, results from the analyses are similar, and conclusions regarding the data refer to both analyses.

For the ANCOVA model, the number of trials to solution on the first letters-to-numbers problem was significant as a covariate, $F(1, 36) = 12.63, p < .01$, partial $\eta^2 = .26$. The main effect of group size on performance was not significant, $F(1, 36) = .23, p = .638$, partial $\eta^2 = .01$. This suggests that, contrary to Hypothesis 1, triads ($M = 4.45$) did not differ significantly from dyads ($M = 4.33$) in their performance. There was a significant main effect of reflexivity condition on performance, $F(1, 36) = 4.42, p < .05$, partial $\eta^2 = .11$. However, opposite to what was predicted in Hypothesis 2, groups in the
reflexivity condition \((M = 4.67)\) performed significantly worse than groups in the control condition \((M = 4.12)\). Finally, the interaction between group size and reflexivity condition on performance was not significant, \(F (1, 36) = 2.25, p = .143, \text{partial } \eta^2 = .06\). This suggests that, contrary to Hypothesis 3, the relationship between reflexivity condition and performance did not depend on group size.

In the second (ANOVA) model, the main effect of group size on performance was also not significant, \(F (1, 37) = .14, p = .714, \text{partial } \eta^2 = .00\). This again suggests that, contrary to Hypothesis 1, triads \((M = 4.45)\) did not differ significantly from dyads \((M = 4.34)\) in their performance. The main effect of reflexivity condition on performance was also not significant in this analysis, \(F (1, 37) = 1.75, p = .194, \text{partial } \eta^2 = .05\). This suggests that, contrary to Hypothesis 2, groups in the reflexivity condition \((M = 4.59)\) did not differ significantly from groups in the control condition \((M = 4.12)\) in their performance. However, the interaction between group size and reflexivity condition on performance was not significant, \(F (1, 37) = 2.25, p = .143, \text{partial } \eta^2 = .06\). This suggests that, contrary to Hypothesis 3, the relationship between reflexivity condition and performance did not depend on group size.
performance was significant, $F(1, 37) = 5.76, p < .05$, partial $\eta^2 = .14$, suggesting that the relationship between reflexivity condition and performance depended on group size. Simple effects tests revealed that in dyads, there was no significant effect of reflexivity condition on performance, $F(1, 19) = .71, p = .409$, partial $\eta^2 = .04$; the performance of dyads groups, groups in the reflexivity condition ($M = 4.18$) did not differ significantly from that of dyads in the control condition ($M = 4.5$). However, in triads, there was a significant effect of reflexivity condition on performance, $F(1, 18) = 5.76, p < .05$, partial $\eta^2 = .24$, with groups in the reflexivity condition ($M = 5.00$) performing significantly worse than groups in the control condition ($M = 3.90$).

Figure 2. Raw mean number of trials used by groups to complete the second letters-to-numbers problem.

Note: Error bars represent 1 standard deviation above and below the mean.
CHAPTER FOUR
DISCUSSION

The purpose of this study was to investigate the unique results of previous studies on the letters-to-numbers task. Participants worked in either two- or three-person groups to complete two letters-to-numbers problems, with a separate task to be completed between problems. Depending on experimental condition, some groups completed a reflexivity task that afforded them the opportunity to develop better strategies and subsequently improve their performance on the second problem, while other groups performed an unrelated task for the same amount of time. It was postulated that the reflexivity task would allow dyads to compensate for a lack of cognitive resources during task performance, and thus enable them to improve their performance. Triads were expected to be naturally superior in strategy development and implementation (thus explaining their typically superior performance) and so the reflexivity manipulation was not expected to cause triads to perform differently. However, this was not the case.

A main effect of group size was expected, with triads outperforming (that is, completing the letters-to-numbers problem in fewer trials) dyads when collapsing across reflexivity condition. No such effect was revealed in the analyses, so Hypothesis 1 was not supported. A main effect of reflexivity condition was also expected, with groups in the reflexivity condition outperforming groups in the control condition when collapsing across group size. In the ANCOVA analysis, there was a significant effect of reflexivity
condition, although it was in the opposite direction to what was predicted—reflexivity groups actually performed significantly worse than control groups, contradicting Hypothesis 2. Additionally, an interaction between group size and reflexivity condition was expected, with dyads receiving greater benefit from the reflexivity task than triads. In the ANOVA analysis, but not in the ANCOVA analysis, a significant interaction was found. However, the data again contradicted predictions. Not only did dyads not benefit from the reflexivity condition, triads in the reflexivity condition actually performed worse than those in the control condition. So Hypothesis 3 was not supported.

The reflexivity task was predicted to affect groups differently depending on group size, which is demonstrated in both analyses, although the results are not what were expected. The logic of the study design considered the reflexivity task as a method to improve dyads’ performance, while not affecting the performance of triads. Instead, the reflexivity condition appears to have had no significant effect on dyads, while actually harming the performance of triads. It is possible that the reflexivity task influenced the strategic abilities of groups in a way that is not fully understood. Instead of merely being redundant for triads’ strategic abilities, the reflexivity manipulation might have disrupted the strategic processes that are assumed to occur within triads, while also failing to catalyze similar (but limited or non-existent) strategic processes in dyads. It may be the case that reflexivity is not an appropriate method of improving group strategy development, strategy implementation, or performance under the circumstances seen in this study.

One limitation of this study stems from the use of the letters-to-numbers task itself. Although an excellent example of an intellective task, and one that has yielded a
unique pattern of results in previous studies, the task may be of limited value in examining the strategy development and implementation abilities of cooperative groups. One specific feature of the task—the ability to guess at any or all of the values of the coded letters—may be particularly problematic. It was not uncommon for groups to realize this as a helpful method of working through the problem, regardless of their successes in using the mathematical equations to arrive at logical answers to the codes. Groups that guess at the value of all letters whenever they have the opportunity to do so were much more likely to perform better than groups that limit their guesses, and groups can recognize this as a sheer law of probability (making all guesses is objectively better than making limited guesses, given that a lucky guess can reveal a letter-number code when there is no logical basis for knowing that code).

While it can be argued that the recognition of this feature of the task is itself a strategic insight, its simplistic nature does not lend itself to true strategic discussion and debate between group members devising clever methods to solve the problem. The low frequencies of the coded behaviors observed during the reflexivity sessions (see Table 1 above) prohibited a comprehensive analysis of the behaviors themselves beyond the frequency data. While serving primarily as a manipulation check to ensure that groups adhered to experimental conditions, the analysis of these behaviors might have provided insight as to the strategy development/implementation process—if only group discussions had been more intense or productive than was observed.

It is possible that improvements to the reflexivity manipulation itself could assist in improving the quality of group discussions. One issue might be the questionable benefit of a reflexivity period; groups that feel their performance could not be improved
would not be motivated to improve their strategies. Presenting groups with negative feedback regarding their performance on the first letters-to-numbers problem (e.g., at least implying, if not outright declaring, that their performance could be improved prior to the reflexivity period) might provide the motivation necessary for groups to engage in strategic discussions. Another adjustment that could be made is forcing groups to develop a specific number of strategy ideas (e.g., at least 5 Explicit strategies) during the reflexivity period, forcing groups to engage in strategic debate to develop these ideas, even if they are not motivated to do so based on their previous performance.

Reflexivity interventions have shown inconsistent effects in past research studies. The reflexivity manipulation used by Gurtner et al. (2007) was expected to improve performance for reflexivity groups over control groups, as well as demonstrate that participants who completed the reflexivity task as a group would perform better than if the participants completed the reflexivity task as individuals. Contrary to expectations, however, groups in the group reflexivity condition did not perform significantly better than control groups, but groups in the individual reflexivity condition did see performance improvements following the intervention. Despite the mixed results, Gurtner et al. (2007) cite their findings as evidence that reflexivity interventions do have the potential to improve performance on group tasks. It may be the case that the reflexivity manipulation used in this study is only applicable for improving group performance under particular group performance conditions not found in this study. The letters-to-numbers task may be limited in demonstrating generalizable findings regarding group performance due to its unique characteristics.
Future studies may benefit from adjustments to (or replacement of) the letters-to-numbers task. One variation of the task used in earlier studies (Laughlin et al., 2002; Laughlin et al., 2003; Laughlin et al., 2006) limited participants to only 1 guess of a letter-to-number code per trial (e.g., A = 3) for which they received feedback as to whether or not the guess was correct. Participants subsequently proposed a full mapping of all 10 letters-to-numbers codes; a fully correct coding solved the problem, otherwise participants continued onto the next trial. This feature significantly alters strategies available to groups attempting to solve the code, as under these circumstances groups cannot follow the “make as many guesses as possible for each trial” strategy described above, for which they would receive specific feedback for as many letters-to-numbers codes as they proposed. Groups would need to be more selective in proposing guesses, and this could result in more focused strategic discussions among group members both during the performance of the task, as well as during any planning periods such as the reflexivity condition discussion period in this study. Alternative versions of the letters-to-numbers problem, or other problem-solving tasks, might result in groups adopting more deliberate strategic approaches to completing the tasks presented to them.

Previous research examining group performance on cooperative problem-solving tasks emphasizes the importance of both group size and task type in understanding how group processes impact performance. The present study adds to the body of literature demonstrating differential effects dependent on group size, although the effects present here contradicted predictions. Limitations of the task structure (both the letters-to-numbers problem and the reflexivity manipulation) potentially contributed to the
unanticipated results, and suggestions for improvements to both components of the task were proposed to guide future research designs.
APPENDIX A

INSTRUCTIONS FOR REFLEXIVITY CONDITION
VERBAL INSTRUCTIONS

You have completed the first problem, and will work on a second problem of the same type in a few minutes. Before doing so, please take 5 minutes to think about how your group performed on the first problem. Consider different ways that may help to improve your performance on this task the second time you try to complete it. You can also think about developing plans to implement these improvements. Your group is encouraged to openly discuss ways to improve your performance. You will be provided materials to record your group’s ideas. After doing this, you will be given another opportunity to solve the same kind of problem with a different random coding of the numbers 0-9 to the letters A-J.
WRITTEN INSTRUCTIONS FOR PARTICIPANTS

• Please discuss ways to improve your performance on the problem the second time you try to complete it.

• Consider different ways that may help to improve your performance.

• Think about developing plans to implement these improvements.

• You will have 5 minutes to come up with ideas. Please use the space on this page to record your ideas. This page will be collected before you begin the second problem.
APPENDIX B

INSTRUCTIONS FOR CONTROL CONDITION
VERBAL INSTRUCTIONS

You have completed the first problem, and will work on a second problem of the same type in a few minutes. Before doing so, however, I would like you to engage in a completely different type of activity for a few minutes. I’d like you to take 5 minutes to think of as many different ways as you can to improve Loyola University from the students’ perspective. There are no restrictions on what you may suggest, and you are encouraged to openly discuss any suggestions with your group. You will be provided materials to record your group’s ideas. After doing this, you will be given another opportunity to solve the same kind of problem as before, with a different random coding of the numbers 0-9 to the letters A-J.
WRITTEN INSTRUCTIONS FOR PARTICIPANTS

- Please discuss ways to improve Loyola University from the students’ perspective.
- Think of as many different suggestions as you can.
- There are no restrictions on what you may suggest.
- You will have 5 minutes to come up with ideas. Please use the space on this page to record your ideas. This page will be collected before you begin the second problem.
APPENDIX C

STRATEGY CODING SCHEME
I. Explicit Strategy – Specific thoughts/suggestions about strategy ideas. Items in this category can be directly implemented by groups and are concrete.

   e.g.:
   “We should use more complex equations.”
   “Maybe using bigger numbers will be more effective.”
   “Should we use longer equations?”
   “We need to solve for more letters at a time.”
   “Maybe it is better to guess about letters we don’t know.”

II. Meta-strategy – General thoughts regarding strategy or characteristics of strategy. Items are more abstract than those in the Explicit Strategy category, and cannot be directly implemented as concise actions. Strategy-related items that are not specific enough to be considered Explicit Strategies fit here.

   e.g.:
   “Let’s evaluate the quality of our equations.”
   “There have to be better strategies out there than what we’re doing.”

III. Strategy Arguments (Supporting/Opposing strategy ideas) – Opinions regarding why any presented ideas are good or bad strategies for improving performance. While the above 2 categories include strategy ideas themselves, this category specifically includes arguments and reasoning for or against any strategy idea.

   e.g.:
   “We can’t use multiplication in our equations because the task doesn’t let us use multiplication.”
   “We should use longer equations because it helps us solve the code faster.”

Both examples above consist of two coded behaviors; the first half of the sentences would be coded as Explicit Strategy behaviors while the bolded portions would be coded as Strategy Arguments. Behaviors categorized as Explicit Strategy or Metastrategy do not have to be followed by Strategy Arguments, but Strategy Arguments must be preceded by behaviors in one of the above categories (either Explicit Strategy or Metastrategy).

IV. Consistency in implementing new Explicit Strategy ideas – On second Letters-to-Numbers problem, instances of groups actually using Explicit Strategies developed during reflection period. Strategies used previously (on first Letters-to-Numbers problem) are not included.
REFERENCE LIST


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