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BRIEF REPORT

Silence Is Golden: The Effect of Verbalization on Group Performance

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Contrary to the popular belief that collaboration brings better problem solutions, empirical studies have revealed that interacting groups often performed worse than noninteracting "nominal" groups. Past studies mainly examined how overhearing others' ideas impacts group performance. This study investigated the impact of another essential but overlooked group communicative process—verbalizing ideas to others—on group performance. Participants ($N = 156$) solved 20 verbal puzzles either alone quietly, alone thinking-aloud, or in verbalizing pairs. Participants in the same working-alone condition were randomly paired to form nominal pairs and their pooled performance was treated as nominal group performance. Relative to the quiet nominal group, the performance of the thinking-aloud nominal and interacting groups were impaired to similar extents. These two groups also demonstrated a similar limited capacity to expand the search scope. The equivalency of the interacting and thinking-aloud nominal group results suggest that verbalization is a key factor in groups' inferior performance.

Keywords: group interaction, verbalization, problem solving

Group work is often the default mode in various problem-solving situations, ranging from industrial-based design to threat assessment. It is a common belief that individuals working together achieve more than they would separately. However, empirical studies have shown the negative effects of group interaction in many domains including memory recall (Basden, Basden, Bryner, & Thomas, 1997), idea generation (Diehl & Stroebe, 1987), decision-making (Kerr & Tindale, 2004), and engineering design (McComb, Cagan, & Kotovsky, 2017). It is suggested that the presence of others can reduce one's effort because of social loafing and/or evaluation apprehension (Camacho & Paulus, 1995; Latané, Williams, & Harkins, 1979). Also, individuals may forget their ideas while waiting for their turn to speak ("production blocking", Diehl & Stroebe, 1987). One way to minimize some of these impacts is to interact nonverbally, for example, computer-mediated communication, providing greater anonymity and control on when to express ideas. Many studies have demonstrated the benefits of computer-mediated interactions over face-to-face interactions on group brainstorming (for a review, see DeRosa, Smith, & Hantula, 2007). However, even in computer-mediated environments, interacting groups can still perform worse than the sum of noninteracting individuals, that is, nominal group (Barki & Pinsonneault, 2001; Kohn & Smith, 2011). For other problem-solving situations, for example, single-solution and decision-making tasks, disadvantages of computer-mediated interactions have been reported (Kerr & Murthy, 2004; O'Neill, Hancock, Zivkov, Larson, & Law, 2016). A synergy whereby interacting groups outperform nominal groups may be difficult to achieve simply by changing the communication medium.

To facilitate group synergy, research has also focused on how group interaction processes impact problem solving. Problem solving often requires searching through memory to retrieve relevant information (Newell & Simon, 1972). Ideally, overhearing others' ideas should enhance this search process. Listening to ideas that are similar to individuals' own ideas could lead to a deeper search, increasing the likelihood of generating high-quality ideas (Baruah & Paulus, 2016; Rietzschel, Nijstad, & Stroebe, 2007). Listening to heterogeneous ideas could bring forth new search directions. However, Rietzschel et al. (2007) demonstrated that although exposure to similar ideas improved idea quality, it reduced the variety of ideas generated. Listening to heterogeneous ideas could also be harmful. During idea retrieval, individuals—who usually have their own retrieval strategy—could be disrupted when over-

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hearing ideas that are misaligned with their own retrieval strategy. Past studies have demonstrated negative effects of group interaction on memory recall (Basden et al., 1997; Weldon & Bellinger, 1997). Such impairment disappeared when group members were instructed to recall items from different categories, presumably reducing retrieval disruption (Basden et al., 1997). To leverage the benefits of group interaction, many studies have investigated the conditions under which overhearing others' ideas becomes facilitating.

Apart from listening to others, individuals also verbalize their thoughts during group interaction. Past studies have devoted little attention to this essential group interaction process. Without knowing whether and how verbalization impacts group performance, it would be impossible to pin down the true cost of group interaction, making cognitive synergy difficult to achieve.

Concurrent verbalization has been shown to direct attention toward aspects of the problem that can easily be accessed and expressed, inhibiting the retrieval of less salient ideas, for example, remote or abstract ideas (Schooler, Ohlsson, & Brooks, 1993). It is possible that verbalization that occurs naturally during group interaction may generate a similar impact, making individuals less likely to retrieve distant ideas that are difficult to access.

This study investigates if group interaction impairs performance on problems that require the retrieval of remote concepts and, more importantly, whether verbalization that occurs naturally during group interaction can account for such negative effects. We examine the performance similarity between think-aloud nominal and interacting groups to determine how much of the effect of group interaction can be attributed to verbalization. Verbal protocols are also analyzed to examine if verbalization and group interaction impact the solution search to similar extents.

Method

Participants

One hundred fifty-six native English-speaking undergraduates at Carnegie Mellon University (M = 78, F = 78, mean age = 19.18, SD = 1.25) participated for course credit. Participants were randomly assigned to solve 20 remote-associate test problems (RAT; Mednick, 1962) either alone quietly, alone thinking-aloud, or in pairs (52 participants per condition). Institutional review board approval was obtained.

Table 1
Proportion of Correct Responses and Solution Time for RAT Problems by Group

	Proportion of correct responses		Solution Time (sec)[a]	
	M	SD	M	SD
Quiet nominal	.57	.14	8.76	2.63
Thinking-aloud nominal	.52	.11	10.84	2.36
Interacting	.51	.11	10.32	2.61

[a] Only solved RAT problems were included.

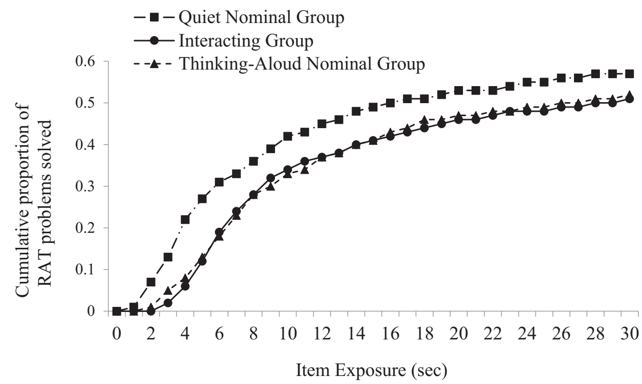

Figure 1. Cumulative proportion of RAT problems solved and mean solution time by group.

Materials

Twenty RAT problems, selected from a normed set (Bowden & Jung-Beeman, 2003), were used as the problem-solving tasks. RAT problems require finding a word that forms a compound word or common phrase with each of the three given cues (e.g., cues: *stick*, *maker*, *point*; answer: *match*). The answer is often remotely associated to the cues. Successful solution requires individuals to search through memory broadly to retrieve remote ideas.

Procedures

Participants were randomly assigned to solve 20 RAT problems either alone quietly (quiet nominal group), alone thinking-aloud (think-aloud nominal group), or in pairs (interacting group). Participants in the think-aloud nominal group had to verbalize all their guesses while solving the problems. Participants in the interacting group were instructed to say all their guesses as soon as they thought of them so that they could be the most help to their group mate.

RAT problems were displayed individually on a computer for 30s. Participants could enter their responses at any point. If their response was correct, the next problem was presented; otherwise, they had the remainder of the time to continue working on the problem. Prior to the experiment, participants had to finish a practice session. During the practice session, participants in the quiet nominal group were given instructions on RAT problems and four practice RAT problems to solve alone. Participant in the interacting and think-aloud nominal groups were first given instructions on RAT problems and two practice RAT problems, and then they were given instructions on how to verbalize their thoughts and two more practice RAT problems in which they had to solve them while thinking-aloud. After the practice, participants in the two nominal groups had to solve 20 RAT problems on a computer alone and participants in the interacting group worked in pairs to solve 20 RAT problems using one computer. Verbal protocols were recorded during the experiment.

Nominal Pairs

Participants in each nominal group were randomly paired to form nominal pairs (26 pairs per group). For each nominal pair, the

Table 2
Number of Repeated and Non-Repeated Ideas, and Semantic-Closeness Score by Group

	Number of repeated ideas				Number of non-repeated ideas				Semantic-closeness score			
	Unsolved trials		Solved trials		Unsolved trials		Solved trials		Unsolved trials		Solved trials	
Group	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Think-aloud	.34	.26	.05	.10	5.30	1.60	1.30	.65	.05	.02	.07	.05
Interacting	.18	.20	.01	.03	3.17	.83	.57	.36	.07	.07	.07	.06

total number of correct responses was the total number of RAT problems solved by at least one participant. If a RAT problem was solved by both participants, the response time of the nominal pair was the response time of the faster participant.

Past studies comparing performance of interacting and nominal groups on idea generation reported an average effect size of $d = -1.398$ (ideation quantity) and -1.143 (ideation quality) indicating negative effects of group interaction (Mullen, Johnson, & Salas, 1991). Having 26 pairs per group gives us a power of over 95% of finding an effect of group interaction, under the assumption that group interaction generates a similar impact on others problems that also require idea retrieval.

Results

RAT Performance

To determine if group interaction impairs RAT performance and whether it can be attributed to verbalization, RAT performance across the quiet nominal, think-aloud nominal, and interacting groups was compared. This comparison was done using survival analysis, an analysis that considers both accuracy and speed by calculating the cumulative proportion of problems solved over time. Table 1 presents descriptive statistics. A significant group difference was found, $\chi^2(2, N = 1560) = 18.11$, $p < .001$. Pairwise comparisons indicated that both the think-aloud nominal and interacting groups performed worse than the quiet nominal group, all $p < .001$. Their diminished performance relative to the quiet group emerged early and persisted throughout the entire problem-solving period. The cumulative proportion of problems solved was very similar between the think-aloud nominal and interacting groups, $p = .78$ (see Figure 1).

Both the think-aloud nominal and interaction groups had to verbalize their ideas during RAT problem solving. The equivalency of the results found for these two groups suggests that the effect of group interaction can be attributed to verbalization. To further confirm this claim, verbal protocols were analyzed to examine if verbalization and group interaction impact the solution search to similar extents.

Verbal Protocol

Coding. For each RAT problem, ideas generated by participants in the same pair were coded into a temporal sequence of ideas, up to the point where the problem was solved by one of the participants or till the end of the 30-s presentation period. Participants sometimes repeated the given cues, these responses were excluded from the sequence. Two interacting pairs were excluded due to technical errors during recording. In total, 24 interacting pairs and 26 think-aloud nominal pairs were coded.

For each problem, the number of repeated and nonrepeated ideas were counted. A repeated idea was an idea that was previously mentioned by one of the participants. For each nonrepeated idea, a semantic-closeness score was computed as the sum of its associative strength to the three given cues, determined by Florida Association Norms (Nelson, McEvoy, & Schreiber, 2004). Table 2 presents descriptive statistics. To determine the characteristics of

Table 3
Linear Mixed-Effects Model of the Number of Non-Repeated Ideas for Unsolved Trials Including Random Effects of Pair and Problem, and a Fixed Effect of Group

	Estimated coefficient	*SE*	95% CI	*t*
Fixed effects				
(Intercept)	.45	.71	−.93, 1.83	.64
Group[a]	.54	.09	.35, .72[b]	5.72
		Name		Variance
Random effects				
Pair effect on intercepts		(Intercept)		1.68
Problem effect on intercepts		(Intercept)		.38

[a] The interacting group was the reference group. 1452 observations, 50 pairs participants, 20 RAT problems. [b] The confidence interval does not include zero, implying that the impact of the fixed effect is significant.

Table 4
Linear Mixed-Effects Model of the Number of Non-Repeated Ideas for Solved Trials Including Random Effects of Protocol Length, Pair, and Problem, and a Fixed Effect of Group

	Estimated coefficient	*SE*	95% CI	*t*
Fixed effects				
(Intercept)	−.20	.30	−.78, .38	−.67
Group[a]	.17	.04	.09, .25[b]	4.51
		Name		Variance
Random effects				
Protocol length		(Intercept)		.53
Pair effect on intercepts		(Intercept)		.05
Problem effect on intercepts		(Intercept)		.12

[a] The interacting group was the reference group. 515 observations, 50 pairs participants, 20 RAT problems. [b] The confidence interval does not include zero, implying that the impact of the fixed effect is significant.

Table 5
Linear Mixed-Effects Model of the Semantic-Closeness Score for Solved Trials Including Random Effects of Problem and Pair, and a Fixed Effect of Group

	Estimated coefficient	*SE*	95% CI	*t*
Fixed effects				
(Intercept)	.092	.054	−.013, .198	1.72
Group[a]	−.004	.009	−.022, .014	−.48

	Name	Variance
Random effects		
Pair effect on intercepts	(Intercept)	<.001
Problem effect on intercepts	(Intercept)	.006

[a] The interacting group was the reference group. 456 observations, 47 pairs, 20 RAT problems.

the solution search, the number of nonrepeated ideas and their semantic-closeness score were examined. A large number of nonrepeated ideas suggests high retrieval fluency, and continuously generating ideas with high semantic-closeness score suggests that the search is confined to typical ideas (Gupta, Jang, Mednick, & Huber, 2012; Shah, Smith, & Vargas-Hernandez, 2003). We are particularly interested in examining whether the think-aloud nominal and interacting groups differed in the semantic-closeness score of ideas generated, given that expanding the search space to remote associates is considered to be a key process underlying RAT problem solving.

Verbal protocols were analyzed using mixed-effects models (Baayen, Davidson, & Bates, 2008). Solved and unsolved trials were analyzed separately because of their difference in protocol length; all of the unsolved trial protocols were 30 seconds long while the protocol length varied across solved trials.

The number of nonrepeated ideas. Mixed-effect models on the number of nonrepeated ideas were constructed for unsolved and solved trials respectively. For unsolved trials, pairs and problems were entered first as random effects, and then, group (interacting or think-aloud) was entered as a fixed effect. The interacting group was the reference group. Similar models were constructed for solved trials except that the protocol length was also included as a random effect.

For both trials, the inclusion of the fixed effect of group significantly improved model fit, unsolved: $\chi(1)^2 = 25.82$, solved: $\chi(1)^2 = 17.71$, all $p < .001$. The think-aloud nominal group generated more nonrepeated ideas than the interacting group, indicated by the positive coefficient of group, coefficient: .54 (unsolved) and .17 (solved). Tables 3 and 4 present model details.

Table 6
Semantic-Closeness Score by Group and Session for Unsolved Trials

	Session					
	1–10 second		11–20 second		21–30 second	
Group	*M*	*SD*	*M*	*SD*	*M*	*SD*
Think-aloud	.072	.047	.039	.025	.039	.037
Interacting	.080	.063	.034	.036	.050	.062

Table 7
Linear Mixed-Effects Model of the Semantic-Closeness Score for Unsolved Trials Including Random Effects of Problem and Pair, and Fixed Effects of Group and Session

	Estimated coefficient	*SE*	95% CI	*t*
Fixed effects				
(Intercept)	.084	.022	.044, .123	4.18
Group[a]	−.0002	.003	−.008, .004	−.54
Session[b]	−.015	.004	−.022, −.007[c]	−4.00

	Name	Variance
Random effects		
Pair effect on intercepts	(Intercept)	<.001
Problem effect on intercepts	(Intercept)	.002

[a] The interacting group was the reference group. 2054 observations, 50 pairs participants, 20 RAT problems. [b] Session 1 was the reference group. [c] The confidence interval does not include zero, implying that the impact of the fixed effect is significant.

Note that being more fluent in generating nonrepeated ideas does not necessarily imply a better solution search; the think-aloud group also generated more repeated ideas than the interacting group did; unsolved: $M = .34$, $SD = .26$ (think-aloud), $M = .18$, $SD = .20$ (interacting), $p = .03$; solved: $M = .05$, $SD = .10$ (think-aloud), $M = .01$, $SD = .03$ (interacting), $p = .10$. Further, both groups solved a similar number of RAT problems. The interacting group may simply be less verbal due to evaluation apprehension. A more critical question is whether these two groups differed in the quality aspect of their solution search, that is, the capacity to expand the search.

The semantic-closeness score. Mixed-effects models were constructed, for solved and unsolved trials respectively, to determine whether the think-aloud nominal and interacting groups differed in the semantic-closeness score of their ideas. For solved trials, the model including only random effects of pairs and problems was similar to the model including also a fixed effect of group, $\chi(1)^2 = .22$, $p = .64$, suggesting a nonsignificant group difference on the semantic-closeness score. Table 5 presents the model including random and fixed effects.

For unsolved trials, similar models were constructed except that the 30-s protocols were divided into three 10-s sessions and that

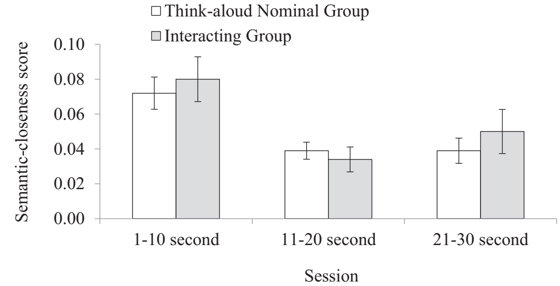

Figure 2. Semantic-closeness score of ideas generated by group and session. Error bars indicate ±1 *SE*.

session (1, 2, or 3) was included in the model to examine the temporal trajectory of the semantic-closeness score (Table 6 presents descriptive statistics). Random effects of pairs and problems were entered first, followed by fixed effects of group and session. Finally, the interaction factor between group and session was added. The interacting group and Session 1 were the reference groups.

The inclusion of fixed effects of group and session improved model fit, $\chi(1)^2 = 17.70$, $p < .001$ (Table 7 presents model details). The coefficient of session was significant and negative: −.015, 95% CI [−.022, −.007], suggesting that later ideas were more remote than earlier ones. A similar trend was found in both groups as neither the effect of group nor its interaction with session was significant—the 95% CI of the coefficient of group included zero [−.008, .004] and the interactive factor between group and session did not impact model fit, $\chi(1)^2 = .03$, $p = .86$.

The nonsignificant results on the semantic-closeness score suggests that the think-aloud nominal and interacting groups were equivalent in terms of their tendency to expand the search to remotely associated ideas.

Discussion

This study compared the effect of thinking-aloud and group interaction on problem solving. Participants solved RAT problems either alone quietly (quiet nominal group), alone thinking-aloud (think-aloud nominal group), or in pairs (interacting group). Both the think-aloud nominal and interacting groups performed worse than the quiet nominal group. The temporal trend in the performance of the think-aloud nominal and interacting groups closely resembled each other; both were worse than the quiet group early on in the study, and the impairment persisted over time. The protocol analysis revealed no significant difference between the think-aloud nominal and interacting groups on the semantic-closeness score of ideas generated, implying a similar limited capacity to expand the search scope in these two groups. Both the think-aloud nominal and interacting groups had to verbalize their ideas while solving RAT problems. The strong similarity of the results found for these two groups suggests that verbalization itself is sufficient to account for the negative effect of group interaction.

RAT problem solving requires the retrieval of remote concepts that are difficult to access. Past studies have shown that think-aloud can induce fixation on easily accessible information (Schooler et al., 1993). Verbalization that occurs naturally during group interaction may induce a similar impact, making it harder to retrieve remote concepts. This explains the finding that think-aloud and group interaction impaired RAT performance to similar extents. Accordingly, reducing the amount of verbalization during group work, for example, limiting interaction duration, should improve group performance particularly for problems that require a broad search of knowledge. Supporting this suggestion, a recent study demonstrated that hybrid groups that involve switching between individual and group work outperformed both nominal and interacting groups on idea generation (Korde & Paulus, 2017).

One may argue that the interacting group's performance could be the result of overhearing others' ideas and production blocking. Although overhearing others' ideas could be stimulating, production blocking might counteract this benefit hindering the interacting group's performance. If so, the performance gap between the quiet and interacting groups should emerge early but diminish gradually because production blocking should be stronger at the beginning, when individuals are likely to think of more ideas than later on (Stroebe, Nijstad, & Rietzschel, 2010). Also, later ideas are usually more novel than earlier ones (Beaty & Silvia, 2012). Overhearing others' ideas should therefore become more facilitating over time, reducing the performance gap. However, in our study, the quiet versus interacting group difference in RAT performance persisted over time. The verbalization account appears to be a better candidate to explain the results.

Though RAT problems may best represent problem that involves specific linguistic representations, we suggest that our study provides generalizations to other problems that also require a broad solution search. Future studies could examine whether verbalization impacts group performance in other problem-solving domains, for example, analogical transfer and conceptual restructuring, where individual problem-solving performance has been shown to be impaired by thinking-aloud (Sieck, Quinn, & Schooler, 1999).

Participants in our study had to verbalize their thoughts but they were not required to explain them, similar to group interaction procedures that focus on idea sharing (Osborn, 1957). However, there are also verbalization procedures that entail explaining thoughts, and facilitating effects of such verbalization on individual problem-solving have been reported (Fox, Ericsson, & Best, 2011). Future studies should compare the impact of different interaction procedures, for example, verbalizing versus explaining thoughts, on group performance.

In sum, our findings suggest that verbalization that occurs naturally during group interaction impairs performance. Past studies mainly focused on maximizing the benefits of overhearing others' ideas. According to our findings, group interaction should also be structured in a way that minimizes the deleterious effects of verbalization.

Context of the Research

Little attention has been devoted to examine how verbalizing ideas to others—an essential communicative process—impacts group performance. Our study compared the effect of thinking-aloud with group interaction on problem solving and revealed that both processes impaired problem solving to similar extents, suggesting that verbalization can account for groups' inferior performance. Our findings offer insight into how group interaction should be structured to maximize performance.

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