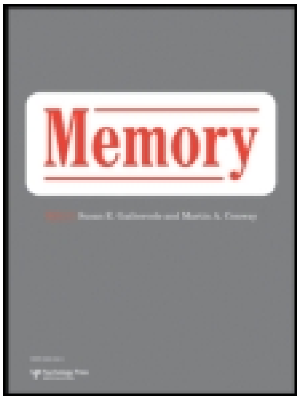

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Expertise promotes facilitation on a collaborative memory task

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Expertise promotes facilitation on a collaborative memory task

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The effect of expertise on collaborative memory was examined by comparing expert pilots, novice pilots, and non-pilots. Participants were presented with aviation scenarios and asked to recall the scenarios alone or in collaboration with a fellow participant of the same expertise level. Performance in the collaborative condition was compared to nominal group conditions (i.e., pooled individual performance). Results suggest that expertise differentially impacts collaborative memory performance. Non-experts (non-pilots and novices) were relatively disrupted by collaboration, while experts showed a benefit of collaboration. Verbal protocol analyses identified mechanisms related to collaborative skill and domain knowledge that may underlie experts' collaborative success. Specifically, experts were more likely than non-experts to explicitly acknowledge partner contributions by repeating back previously made statements, as well as to further elaborate on concepts in those contributions. The findings are interpreted according to the retrieval strategy disruption theory of collaborative memory and theories of grounding in communication.

Keywords: Collaborative memory; Expertise.

Collaborative memory occurs when people work together to jointly remember a past event. While there is much evidence that at the group level of analysis, collaborative groups remember more than individuals (e.g., Dixon, 1999), there is also evidence that at the individual level of analysis, each individual remembers less when working in a group relative to working alone, a finding termed *collaborative inhibition* (Weldon & Bellinger, 1997). Collaborative inhibition is measured by comparing the pooled unique responses produced by each individual working alone (a nominal group; see Lorge & Solomon, 1955) with the combined, unique responses produced by individuals working with others (a collaborative group). There is currently great interest in identifying factors that predict when collaboration produces inhibition or facilitation outcomes compared to working alone. The current experiment compares experts and novices to

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gain leverage on factors related to differential success in collaboration.

The collaborative inhibition effect has been demonstrated in a variety of contexts including veridical recall (e.g., Andersson & Ronnberg, 1996) and false recall (e.g., Basden, Basden, Thomas, & Souphasith, 1998), as well as for different populations including young adults (e.g., Wright & Klumpp, 2004) and older adults (e.g., Johansson, Andersson, & Ronnberg, 2000). In previous demonstrations, collaborative inhibition has been obtained in participants who are essentially novices (that is, participants are asked to remember information unrelated to any expertise they may have). Our rationale for examining the role of expertise on collaborative memory is motivated by the retrieval strategy disruption hypothesis of collaborative inhibition (Basden, Basden, Bryner, & Thomas, 1997). According to the retrieval strategy disruption hypothesis, individuals approach a memory task with their own idiosyncratic strategy for remembering and producing information. At retrieval, individuals output the items in an order consistent with their particular strategy. To the extent that partners working on a joint task have different optimal orders of output at retrieval, one partner's output may disrupt the other partner's strategy for remembering information.

Expertise-related differences regarding retrieval strategy disruption may be related to experts' domain knowledge and/or collaborative skill (see Cooke, Gorman, Duran, & Taylor, 2007, for a related distinction between team knowledge and team process). Domain knowledge consists of knowledge of concepts, facts, and procedures relevant to the task (see Ericsson, Charness, Feltovich, & Hoffman, 2006). By definition, experts possess great amounts of domain knowledge in their area of expertise. Collaborative skill consists of procedures relevant to coordinating information sharing in a group setting such as acknowledging others' contributions and managing joint attention on the task (cf. Clark, 1996; Ekeocha & Brennan, 2008). Experts in different domains are likely to vary in their level of collaborative skill. We investigated the impact of domain knowledge and collaborative skill on collaborative memory among aviation experts because pilots receive training in collaborative skill as well as domain knowledge. Note that we conflated domain knowledge and collaborative skill in our expert population because collaborative inhibition is a robust effect, and we wanted to maximise the likelihood of demonstrating collaborative facilitation on the memory task. Further, the nature of the relationship between domain knowledge and collaborative skill has yet to be determined; it may be that either type of process alone is sufficient for collaborative success, or it may be that both types of processes in conjunction promote collaborative success. The relative contribution of domain knowledge and collaborative skill to collaborative outcomes is explored in our verbal protocol analyses.

Research on individual expertise suggests several reasons why experts' domain knowledge may reduce the likelihood of retrieval disruption and ultimately collaborative inhibition. First, individual experts recall more information from domain-relevant materials than novices (e.g., Vicente & Wang, 1998), most likely because they organise large amounts of knowledge into chunks that can be easily accessed from memory (Chase & Simon, 1973; Ericsson & Kintsch, 1995; Gobet & Simon, 2000; Koedinger & Anderson, 1990). Further, experts process information differently from novices, for example by spending more time on information critical to the problem (Morrow et al., 2008; Shanteau, 1992). Regarding collaboration, two experts within the same domain are likely to agree on which information is critical, and to use similar encoding strategies to organise the novel information into their existing knowledge structures (assuming they use that knowledge in similar ways, e.g., Lynch, Coley, & Medin, 2000). Similar encoding between participants eliminates collaborative inhibition (Basden et al., 1997; Finlay, Hitch, & Meudell, 2000), so experts' similar encoding strategies may minimise disruption at retrieval. Second, experts' rapid and reliable access to knowledge mitigates effects of interruption—once interrupted they more rapidly resume the task compared to novices (Ericsson & Kintsch, 1995). Regarding collaboration, experts might be relatively less disrupted by a partner's contribution that differs from theirs.

Experts may perform differently from novices on a collaborative memory task because of collaborative skill as well as domain knowledge. Experts in our study were licensed pilots with instrument ratings. They are likely to have high levels of collaborative skill because of their aviation experience, including training in crew resource management (CRM) (see Sherman, 2003, for an overview). In CRM, pilots are trained to communicate with each other (Kanki, Lozito, & Foushee, 1989) and with air traffic control

(Morrow, Rodvold, & Lee, 1994). Specifically, pilots are trained to acknowledge new contributions by repeating back information in order to explicitly indicate that information is mutually understood before moving on to new information or a new transaction (Morrow et al., 1994) Thus, aviation is a domain in which collaborative skill is essential for utilising domain knowledge; pilots must effectively communicate to accomplish joint tasks such as flying an aeroplane. Regarding collaborative memory, pilots' collaborative skill may result in more effective management of each individual's contributions (e.g., fewer interruptions). Also, because collaborative processes such as turn taking and incorporating contributions require cognitive resources (Steiner, 1972; see also Ekeocha & Brennan, 2008), expert pilots may be less susceptible to this cognitive overhead because they have developed effective communication skills to deal with such information-sharing tasks. To sum up so far, reducing the disruptive effects of collaboration via overlapping domain knowledge and/or enhanced collaborative skill should mitigate the inhibition effect, so that pooled individual and collaborative groups perform equivalently.

Expertise may also promote facilitation on collaborative tasks, so that individuals derive a benefit from working in groups. Johansson, Andersson, and Ronnberg (2005) found that older adult couples who agreed on a high division of responsibility for remembering different information showed a trend towards collaborative facilitation. Ross, Spencer, Linardatos, Lam, and Perunovic (2004) found that collaborative facilitation might be obtained via error correction; collaborative groups are more accurate than pooled groups because they eliminate errors produced by individual members. One idea that has received little support is that collaboration can benefit group members through cross-cueing. Cross-cueing refers to retrieving information that would not be retrieved individually because of something said by one's partner (see Meudell, Hitch, & Boyle, 1995; Meudell, Hitch, & Kirby, 1992). Past research has been unsupportive of cross-cueing (Meudell, et al., 1992, 1995), but it may be that some groups of participants are better able than others to cross-cue each other. In particular, overlap in experts' knowledge structures may provide a foundation for cross-cueing. One measure of cross-cueing may be greater joint elaboration on a single concept before moving on to the next idea. A second measure is the order of recall across turns; one partner's recall may cue the other to recall the next concept in a scenario.

Little experimental research has investigated the impact of expertise on collaborative cognition; none has examined the role of expertise on a laboratory collaborative memory task. However, there is a vast literature on team processes and distributed decision making (see Kozlowski & Ilgen, 2006, for a review). While this includes studies on expertise and optimal group performance, these studies (unlike the current study) are typically limited to teams, a special kind of group in which individuals have different responsibilities associated with a common team task (Salas, Dickinson, Converse, & Tannenbaum, 1992). Research on transactive memory (Wegner, Erber, & Raymond, 1991) has also examined expertise and collaboration, but is again typically focused on information distributed among collaborators and often includes perceptions of expertise rather than actual acquired expertise (e.g., Hollingshead, 2000; see also Pasupathi, Alderman, & Shaw, 2007). There are also observational data on collaboration among experts with different knowledge (e.g., medical doctors and computer scientists collaborating; Patel, Allen, Arocha, & Shortliffe, 1998). Finally, Wiley and Jolly (2003) provide evidence that experts may benefit from collaborating with novices when expert knowledge interferes with the correct solution on a problem-solving task. In contrast to previous research, the current experiment focuses on memory performance for shared information and also provides verbal protocol analyses of on-line cognitive processes that may identify processes related to different levels of success on a collaborative memory task.

METHOD

Participants

A total of 32 expert pilots, 32 novice pilots, and 32 non-pilots participated. Expert and novice pilots were recruited from the Institute of Aviation at the University of Illinois Urbana Champaign (UIUC). Experts were flight instructors at the Institute with instrument ratings and commercial licences. Novices were students recruited from entry-level aviation classes who did not yet have private licences. Non-pilots were undergraduate students who reported no aviation-relevant experience.

TABLE 1

Mean number of flight hours (VFR+IFR), piloting skills score, age (in years), education (in years), Shipley vocabulary score, digit comparison score, and pattern comparison score for experts, novices, and non-pilots

	Experts	*Novices*	*Non-pilots*
Flight hours	884.8 (1243.90)	45.6 (122.28)	0 (0)
Piloting skills[1]	15.5 (4.95)	11.6 (2.68)	8.5 (2.36)
Age	23.5 (5.31)	19.0 (1.51)	21.1 (1.78)
Education	15.4 (1.82)	12.8 (1.14)	15.4 (1.90)
Shipley[2]	31.1 (4.0)	29.6 (4.17)	30.2 (4.32)
Digit comparison[3]	72.2 (8.94)	70.4 (12.60)	77.7 (12.28)
Pattern comparison[3]	60.9 (6.73)	61.9 (7.83)	61.7 (12.87)

Standard deviations are in parentheses ($N = 96$).

[1] From Morrow, D. G., Menard, W. E., Stine-Morrow, E. A. L., Teller, T., & Bryant, D. (2001). The influence of task factors and expertise on age differences in pilot communication. *Psychology and Aging*, *16*, 31–46.

[2] Shipley, W. C. (1946). *Institute of living scale.* Los Angeles Western Psychological Services.

[3] Salthouse, T. A., & Babcock, R. (1991). Decomposing adult age differences in working memory. *Developmental Psychology*, *27*, 763–776.($N = 96$). Standard deviations are in parentheses.

Participants' mean number of flight hours—Visual Flight Rules (VFR) plus Instrument Flight Rules (IFR)—and mean score on a piloting skills questionnaire are presented in Table 1. The piloting skills questionnaire was taken from Morrow, Menard, Stine-Morrow, Teller, and Bryant (2001) who adapted the FAA instrument rating exam into a survey of 20 questions regarding navigation and air traffic control concepts and reported its test–retest reliability as $r = .79$. Separate one-way ANOVAs revealed an expertise difference in the mean number of flight hours, $F(2, 93) = 14.59$, $MSE = 79.85$, and scores on the piloting skills questionnaire, $F(2, 93) = 32.03$, $MSE = .46$. Importantly, post hoc comparisons confirmed that experts had a greater number of flight hours than novices, $t(62) = 3.64$, $SEM = 213.15$, and novices had a greater number of flight hours than non-pilots, $t(62) = 2.16$, $SEM = 22.25$. Experts also had significantly higher scores on the piloting skills questionnaire than did novices, $t(62) = 3.96$, $SEM = .99$, and novices had higher scores than non-pilots, $t(62) = 4.91$, $SEM = .63$.

Table 1 also presents neuropsychological data (Shipley vocabulary (Shipley, 1946); digit comparison and pattern comparison (Salthouse & Babcock, 1991)) and demographic data. Separate one-way ANOVAs revealed that the groups did not differ in Shipley vocabulary scores or pattern comparison scores, $F\text{s} < 1.0$. However, they did differ in age, $F(2, 93) = 14.14$, $MSE = .39$, education, $F(2, 93) = 25.92$, $MSE = .21$, and digit comparison scores, $F(2, 93) = 3.60$, $MSE = 1.2$. Post hoc analyses revealed that the experts were older than both novices, $t(62) = 4.58$, $SEM = .98$, and non-pilots, $t(62) = 2.36$, $SEM = 1.0$, and that the novices had less education than the experts, $t(62) = 6.75$, $SEM = .38$, and the non-pilots, $t(62) = 6.62$, $SEM = .39$, who did not differ from each other, $t < 1.0$. Finally, novices and experts did not differ from each other on the digit comparison task, $t < 1.0$, but both groups performed worse than the non-pilots, $t(62) = 2.36$, $SEM = 2.1$, and $t(62) = 2.05$, $SEM = 2.6$, respectively. The group differences in age and digit comparison favoured the non-pilots, and worked against the predicted expertise benefits for individual and collaborative performance. Finally, there was no difference between groups in partner familiarity (3 of 8 expert pairs, 2 of 8 novice pairs, and 0 of 8 non-pilots had met each other prior to the experiment, $\chi^2 = 3.54$, $p = .171$), so we expected no confound of partner familiarity on collaborative inhibition effects (cf. Andersson & Ronnberg, 1995). Further, an independent samples t test confirmed that the mean recall of expert pairs who had met prior to the experiment ($M = .71$) did not differ from the mean recall of experts pairs who had not met prior to the experiment ($M = .66$), $t(6) = .41$, $SEM = .05$, $p = .70$; the majority of partners claiming they had met previously indicated they interacted only occasionally.

Design

The experiment employed a 3 (expertise level: non-pilots, novices, or experts) × 2 (recall: individual or collaborative) × 2 (scenario complexity: simple or complex) mixed design. Expertise level and recall condition were manipulated between participants and scenario complexity was manipulated within participants. Dependent variables included the proportion of accurate recall and measures of processes related to domain knowledge and collaborative skill obtained via verbal protocol analyses.

Materials

Simple and complex scenarios outlining flight situations in which problems arise were selected from Morrow et al. (2008). See the Appendix for an example. Ratings by commercial airline pilots confirmed that problems in the complex scenarios had fewer obvious solutions than problems in the simple scenarios. We predicted that expertise benefits might be greater for more complex scenarios because they required more domain knowledge to be understood.

Procedure

Participants were presented with four scenarios and read them at their own pace in preparation for a memory test. After a 1-minute filler task intended to eliminate rehearsal in short-term memory, participants were asked to recall aloud and write down as much information as possible from each of the scenarios without guessing. Half of the participants were asked to recall the scenarios individually and half were asked to recall the scenarios in collaboration with another participant of the same expertise level. Participants in the collaborative recall condition designated one participant to write down information recalled; they were given no special instructions on how to work with each other regarding coming to a consensus or solving disagreements. Next, participants completed a problem-solving task (not reported here) and then completed the demographic and neuropsychological assessments provided in Table 1. Finally, participants were debriefed and paid $8 per hour for participation.

RESULTS

Recall

TABLE 2

Mean proportion of segments recalled by experts, novices, and non-pilots as a function of individual or collaborative recall

	Experts	*Novices*	*Non-pilots*
Pooled individual	.52 (.18)	.51 (.13)	.41 (.10)
Collaborative	.68 (.15)	.46 (.08)	.33 (.14)
Individual	.33 (.16)	.28 (.14)	.23 (.11)
Effect Size	.97	−.48	−.67

Standard deviations are in parentheses. Effect size is based on a comparison between pooled individual and collaborative conditions ($N = 96$).

Table 2 presents the mean proportion of correct scenario segments in the written recall protocols produced by experts, novices, and non-pilots as a function of individual or collaborative recall. Segments reflect single idea units and were scored according to details recalled (e.g., for the segment "the number two generator fails", participants who recalled nothing about the generator received 0 for that segment, participants who recalled "the generator fails" received 1, and participants who recalled "the number two generator fails" received 2). Data were coded independently by the first author and a research assistant with aviation experience (the Kappa coefficient showed very high inter-rater reliability, $\kappa = .964$; discrepancies were resolved via discussion). Both average and pooled measures of individual performance are reported. Pooled groups were created as a function of participant number as is standard in collaborative memory research (cf. Weldon & Bellinger, 1997; see Wright, 2007, for an alternate method that was not possible here due to counterbalancing constraints). Statistical significance is set at $p \leq .05$ unless otherwise noted.

Because preliminary analyses revealed no effect of scenario complexity nor interactions between scenario complexity and other variables (Fs < 1.0) possibly due to low power, we collapsed over this variable for the primary analyses (see Table 2). A 3 (expertise: experts, novices, or non-pilots) × 2 (recall: pooled individual or collaborative) ANOVA conducted on the mean proportion of recall revealed a significant main effect of expertise, $F(2, 42) = 11.42$, $MSE = .02$. Experts ($M = .60$ collapsing across pooled and collaborative groups) recalled significantly more segments than novices ($M = .49$), $t(30) = 2.17$, $SEM = .05$, and non-pilots ($M = .37$), $t(30) = 4.12$, $SEM = .05$. Further, novices recalled more segments than the non-pilots, $t(30) = 2.83$, $SEM = .04$. Note also that non-pooled individual experts (measured at the individual level rather than the dyad level) recalled marginally more segments than did non-pilots, $t(30) = 1.94$, $SEM = .04$, $p = .06$, which is consistent with earlier work showing an advantage for individual experts on domain relevant tasks (Morrow et al., 2008).

Most interesting is the relationship between expertise and collaboration. The ANOVA revealed a significant interaction between expertise level and recall condition, $F(2, 42) = 3.44$, $MSE = .02$. To better understand the interaction, a simple effects analysis was conducted for each type of recall. Looking first at pooled individual recall, the ANOVA revealed no difference in the mean proportion of recall between experts, novices, and non-pilots, $F(2, 21) < 1.6$. In contrast, there was a significant effect of expertise on recall in collaborative groups, $F(2, 21) = 14.16$, $MSE = .02$. Experts ($M = .68$) recalled significantly more in collaborative groups than novices, ($M = .46$), $t(14) = 3.41$, $SEM = .06$, and novices recalled more than non-pilots, ($M = .33$), $t(14) = 2.29$, $SEM = .06$. The difference in collaborative recall between participant groups is especially interesting in light of the finding that pooled individual recall between participant groups did not vary. Inspection of the means reveals a cross-over effect demonstrating that both non-pilots and novices recalled less in collaborative groups ($M = .33$, $M = .46$ respectively) than in pooled individual groups ($M = .41$, $d = -.67$; $M = .51$, $d = -.48$ respectively), while experts in collaborative groups ($M = .68$) recalled *more* than the pooled recall of individual experts ($M = .52$), $t(14) = 1.80$, $SEM = .08$, $p = .045$ one-tailed, $d = .97$, indicating collaborative facilitation. Collaborative facilitation is rare (see Ross et al., 2004, and Johansson et al., 2005, for examples). Aviation experts may have benefited from collaboration because their expertise includes training in collaborative skill as well as shared domain knowledge. To better understand the mechanisms underlying collaborative facilitation for aviation experts, we analysed verbal protocols from the collaborative condition.

Verbal protocols

All experimental sessions were audio taped, transcribed, and coded for processes indicative of domain knowledge and collaborative skill.[1]

TABLE 3
Mean number of statements and turns generated by experts, novices, and non-pilots

	Experts	*Novices*	*Non-pilots*
Number of turns	61.13 (18.53)	38.19 (5.25)	33.75 (6.65)
Effect size		1.93*	2.17*
Number of statements	106 (27)	66 (8.48)	57 (3.53)
Effect size		2.25*	3.21*

($N = 96$). Standard deviations are in parentheses. Effect size is based on a comparison between experts and novices, and experts and non-pilots. * indicates $d > .80$; $^+$ indicates $.80 > d > .20$.

The following analyses examine the top four groups from each condition who had the highest recall. We focus on these groups because we are interested in determining whether there are different collaborative processes underlying group performance when collaborators are most successful. Protocol analyses are descriptive and provide insight into the processes underlying experts' memory advantage. Rather than conduct null hypothesis significance tests on these data (inappropriate given the low N), we focused on data patterns and effect sizes. According to Cohen (1988) effect sizes should be considered large when $d > .80$, medium when $.80 > d < .20$, and small when $d < .20$.

Table 3 shows the average number of statements generated and turns taken by each participant group. *Statements* were defined by clauses and pauses longer than 3 seconds and *turns* were defined by a transition to a new speaker. Experts generated approximately 1/3 more statements and turns (approximately 2 *SD* more) than non-experts, a result consistent with experts' recall advantage (see Morrow et al., 2008, for similar findings).

Protocols were coded for processes indicative of domain knowledge and collaborative skill. To assess the reliability of the coding scheme two coders (the second author and a research assistant) independently coded a sub-sample of the protocols. The coders showed high agreement ($\kappa = .876$) and discrepancies were resolved via discussion. The remaining protocols were coded by a single coder with the second coder re-checking all the codes. Any discrepancies were resolved via discussion.

Domain knowledge processes included *elaborations* (providing additional detail for a statement generated by one's partner), *corrections*

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[1] Two expert tapes could not be transcribed due to data loss; one expert and one novice tape could not be transcribed due to poor sound quality.

(correcting inaccurate information in a previous statement), *explanations* (providing a rationale of a previous statement), and *questions* (asking for additional information and/or questioning the content of the previous statement). These processes reflect domain knowledge because they are content-based; participants relied on aviation knowledge to elaborate on, correct, explain, or question the information previously stated.

Processes reflecting collaborative skill were not tied to the content of previous statements, but rather reflected how participants acknowledged partner contributions and maintained attention to the task. Collaborative skill processes included *simple acknowledgements* (''ok'' or ''yeah'' responses), *repetitions* (repeating back the previous statement), and *restatements* (rephrasing the previous statement). Each of these collaborative skill processes has been shown to influence group performance by establishing the common ground necessary to achieve joint goals (Clark & Wilkes-Gibbs, 1986).

We also calculated the average distance between statements across turns as a function of the order in which statements occurred in the scenario. Lower distance scores indicate that participants were recalling statements from adjacent parts of the scenarios, whereas higher scores indicate a larger distance between statements recalled. This measure assesses one aspect of cross-cueing; recalling one statement facilitates a partner's memory for a related (next or previous) statement from the scenario.

The average proportion of statements classified under each code, as well as the distance score, is presented in Table 4. Looking first at domain knowledge processes, experts in collaborative situations were more likely to elaborate on a partner's previous statement ($M = .103$) than were novices ($M = .057$; $d = 1.21$) and non-pilots ($M = .068$; $d = 1.15$), so that after talking with each other, experts ended up with a more detailed version of information presented in the scenario. For example, person A said: ''a twin engine took off'', person B elaborated: ''took off to the left''. This type of elaboration may be similar to the notion of cross-cueing as participants were adding information as a result of what their partner said. In addition, experts had lower distance scores than novices ($M = 3.03$ and $M = 4.21$ respectively; $d = 2.43$) and non-pilots ($M = 4.20$; $d = 2.34$) showing that experts recalled information that was closer together in the scenario than non-experts. Experts also showed moderate to large advantages over novices and non-pilots in the proportion of statements to include explanations ($d = .35$; $d = .91$) and corrections ($d = .38$; $d = 1.70$). However, they did not differ from the novices in the proportion of questions generated ($d = .04$) and made moderately fewer questions than non-pilots ($d = -.49$).

TABLE 4

Mean proportion of statements classified under each code of domain knowledge processes and collaborative skill processes

	Experts	*Novices*	*Non-pilots*
Domain Knowledge			
Elaborations	.103 (.047)	.057 (.029)	.068 (.014)
Effect size		1.21*	1.15*
Corrections	.035 (.018)	.030 (.008)	.012 (.009)
Effect size		.38^{+}	1.70*
Explanations	.064 (.058)	.051 (.016)	.034 (.008)
Effect size		.35^{+}	.91*
Questions	.111 (.031)	.110 (.025)	.129 (.042)
Effect size		.04	$-.49^{+}$
Distance score	3.03 (.34)	4.21 (.63)	4.20 (.66)
Effect size		2.43*	2.34*
Collaborative Skill			
Acknowledgements	.162 (.113)	.177 (.060)	.217 (.053)
Effect size		$-.17$	$-.66^{+}$
Repetitions	.090 (.036)	.071 (.020)	.047 (.013)
Effect size		.68^{+}	1.76*
Restatements	.086 (.047)	.052 (.012)	.074 (.036)
Effect size		1.15*	.29^{+}

($N = 4$ pairs per condition). Standard deviations are in parentheses. Effect size is based on a comparison between experts and novices, and experts and non-pilots. * indicates $d > .80$; + indicates $.80 > d > .20$.

Experts also demonstrated a different pattern of collaborative skill from non-experts. Specifically, experts ($M = .09$) were more likely than novices ($M = .07$, $d = .68$) and non-pilots ($M = .05$, $d = 1.76$) to repeat back statements. Experts ($M = .086$) were also more likely than novices ($M = .052$; $d = 1.15$) and non-pilots ($M = .074$; $d = .29$) to restate previous statements. In contrast, novices ($M = .177$) and non-pilots ($M = .217$) were more likely to use simple acknowledgements than were experts ($M = .162$; $d = -.17$; $d = -.66$ respectively). While all types of acknowledgements establish a common ground between partners (Clark & Wilkes-Gibbs, 1986), repetitions and restatements indicate explicitly what content the collaborators agree is in common ground, and thus may more effectively support joint attention to relevant information.

Taken together, these findings suggest that aviation experts repeated and restated the content of the previous statement and then elaborated on the content of that statement. Novices and non-pilots, on the other hand, were more likely to use simple acknowledgments and not follow up with any elaborations.

GENERAL DISCUSSION

The current study provides a novel comparison of expertise differences on a domain-relevant collaborative memory task. Several important findings resulted from this comparison. Most exciting, experts demonstrated collaborative facilitation while novices and non-experts showed the typical collaborative inhibition effect. Verbal protocol analyses suggested that aviation experts were successful collaborators because they were more likely to repeat back their partner's contribution (collaborative skill), which provided a platform for further elaborating on this information (domain knowledge). As mentioned previously, aviation expertise includes training on effective communication and this training most likely facilitated experts' information exchange in the current study.

Results of this study are consistent with the retrieval strategy disruption hypothesis of collaborative memory. Basden et al. (1997) established that similar encoding strategies encourage similar orders of output at retrieval and so minimise disruption and eliminate collaborative inhibition. Experts encode information differently from novices (e.g., Morrow et al., 2008), and because our experiment included homogeneous expert pairs (flight instructors with similar types of flight experience) it is likely that they encoded information in similar ways, which minimised the disruptive effects of the collaborative memory task.

Most important, experts in our study went beyond minimising collaborative inhibition and showed facilitation. One mechanism through which additional information was produced during collaboration was elaborations. Experts' statements likely cued their partners to elaborate further on the concept, which is consistent with the retrieval strategy disruption hypothesis because it suggests that experts jointly spent time discussing the same aspect of the scenario before moving onto a different concept.

Results of the current study are also consistent with past research on conversational processes and group outcomes. Aviation experts were more likely to repeat back and then elaborate on previous statements, a finding consistent with past research showing (1) that successful groups are more coherent in that ideas offered by one member are often related to ideas previously offered by a different member (Barron, 2003), and (2) that groups who are more successful on collaborative learning (Barron, 2003) and problem solving (Fischer, McDonnell, & Orasanu, 2007) tasks are more likely to accept and discuss rather than ignore member contributions. It is also consistent with the finding that members of better-performing airline crews are more likely to explicitly acknowledge each others' contributions by repeating, or "reading back" new information (Kanki et al., 1989). More generally, conversational analysis shows that partners successfully coordinate action when they effectively manage joint attention to relevant information in common ground (Clark, 1996).

This study shows that expertise influences the processes involved in collaborative memory and that aviation experts in particular are successful collaborators because they possess domain knowledge and collaborative skills relevant to the task. Identifying possible mechanisms underlying collaborative success among experts provides an important starting point for future research to examine whether both domain knowledge and collaborative skill are required for collaborative success to occur. If so, collaborative success would be less likely for expert populations not explicitly trained in collaborative skill. Future work should also validate our protocol measures as unique indices of domain knowledge or collaborative skill processes and work to determine the nature of the relationship between domain knowledge and collaborative skill.

It is also important to investigate collaboration in more realistic task environments and to develop measures of collaborative processes in these contexts. For example, Schriver, Morrow, Wickens, and Talleur (2008) found that experts more quickly and accurately detected and responded to problems during simulated single-pilot flights, in part because of attentional strategies as measured by eye tracking. Expertise benefits may be especially likely for multi-pilot operations, reflecting collaborative processes that could be measured by eye tracking.

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REFERENCES

Andersson, J., & Ronnberg, J. (1995). Recall suffers from collaboration: Joint recall effects of friendship and task complexity. *Applied Cognitive Psychology*, *9*, 199–211.

Andersson, J., & Ronnberg, J. (1996). Collaboration and memory: Effects of dyadic retrieval on different memory tasks. *Applied Cognitive Psychology*, *10*, 171–181.

Barron, B. (2003). When smart groups fail. *The Journal of Learning Sciences*, *12*, 307–359.

Basden, B. H., Basden, D. R., Bryner, S., & Thomas, R. L., III. (1997). A comparison of group and individual remembering: Does collaboration disrupt retrieval strategies? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *23*, 1176–1189.

Basden, B. H., Basden, D. R., Thomas, R. L. III, & Souphasith, S. (1998). Memory distortion in group recall. *Current Psychology: Developmental, Learning, Personality, Social*, *16*, 225–246.

Chase, W. G., & Simon, H. A. (1973). *Perception in chess. Cognitive Psychology*, *4*, 55–81.

Clark, H. H. (1996). *Using language*. Cambridge, UK: Cambridge University Press.

Clark, H. H., & Wilkes-Gibbs, D. (1986). Referring as a collaborative process. *Cognition*, *22*, 1–39.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed). Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

Cooke, N. J., Gorman, J. C., Duran, J. L., & Taylor, A. R. (2007). Team cognition in experienced command-and-control teams. *Journal of Experimental Psychology: Applied*, *13*, 146–157.

Dixon, R. A. (1999). Exploring cognition in interactive situations: The aging of n + 1 minds. In T. M. Hess & F. Blanchard-Fields (Eds.), *Social cognition and aging*. San Diego, CA: Academic Press.

Ekeocha, J. O., & Brennan, S. E. (2008). Collaborative recall in face-to-face and electronic groups. *Memory*, *16*, 245–261.

Ericsson, K. A., Charness, N., Feltovich, P. J., & Hoffman, R. R. (2006). *The Cambridge handbook of expertise and expert performance*. New York: Cambridge University Press.

Ericsson, K. A., & Kintsch, W. (1995). Long term working memory. *Psychological Review*, *102*, 211–245.

Finlay, F., Hitch, G. J., & Meudell, P. R. (2000). Mutual inhibition in collaborative recall: Evidence for a retrieval based account. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *26*, 1556–1567.

Fischer, U., McDonnell, L., & Orasanu, J. (2007). Linguistic correlates of team performance: Toward a tool for monitoring team functioning during space missions. *Aviation, Space, and Environmental Medicine*, *78*, 86–95.

Gobet, F., & Simon, H. A. (2000). Five seconds or sixty? Presentation time in expert memory. *Cognitive Science*, *24*, 651–682.

Hollingshead, A. B. (2000). Perceptions of expertise and transactive memory in work relationships. *Group Processes & Intergroup Relations*, *3*, 257–267.

Johansson, N. O., Andersson, J., & Ronnberg, J. (2005). Compensating strategies in collaborative remembering in very old couples. *Scandinavian Journal of Psychology*, *46*, 349–359.

Johansson, O., Andersson, J., & Ronnberg, J. (2000). Do elderly couples have a better prospective memory than other elderly couples when they collaborate? *Applied Cognitive Psychology*, *14*, 121–133.

Kanki, B. G., Lozito, S., & Foushee, H. C. (1989). Communication indices of crew coordination. *Aviation, Space, Environmental Medicine*, *60*, 56–60.

Koedinger, K. R., & Anderson, J. R. (1990). Abstract planning and perceptual chunks: Elements of expertise in geometry. *Cognitive Science*, *14*, 511–550.

Kozlowski, S. W. J., & Ilgen, D. R. (2006). Enhancing the effectiveness of work groups and teams. *Psychological Science in the Public Interest*, *7*, 77–124.

Lorge, J., & Solomon, H. (1955). Two models of group behavior in the solution of eureka-type problems. *Psychometrika*, *20*, 139–148.

Lynch, E. B., Coley, J. D., & Medin, D. L. (2000). Tall is typical: Central tendency, ideal dimensions and graded category structure among tree experts and novices. *Memory and Cognition*, *28*, 41–50.

Meudell, P. R., Hitch, G. J., & Boyle, M. M. (1995). Collaboration in recall: Do pairs of people cross-cue each other to produce new memories? *The Quarterly Journal of Experimental Psychology*, *48*, 141–125.

Meudell, P. R., Hitch, G. J., & Kirby, P. (1992). Are two heads better than one? Experimental investigations of the social facilitation of memory. *Applied Cognitive Psychology*, *6*, 525–543.

Morrow, D. G., Menard, W. E., Stine-Morrow, E. A. L., Teller, T., & Bryant, D. (2001). The influence of task factors and expertise on age differences in pilot communication. *Psychology and Aging*, *16*, 31–46.

Morrow, D. G., Miller, L. M. S., Ridolfo, H. E., Magnor, C., Fischer, U. M., Kokayeff, N. K., & Stine-Morrow, E. A. L. (in press). Expertise and age differences in pilot decision making. *Aging, Neuropsychology, and Cognition*.

Morrow, D. G., Rodvold, M., & Lee, A. (1994). Nonroutine transactions in controller–pilot communication. *Discourse Processes*, *17*, 235–258.

Pasupathi, M., Alderman, K., & Shaw, D. (2007). Talking the talk: Collaborative remembering and self-perceived expertise. *Discourse Processes*, *43*, 55–77.

Patel, V. L., Allen, V. G., Arocha, J. F., & Shortliffe, E. H. (1998). Representing clinical guidelines in GLIF: Individual and collaborative expertise. *Journal of the*

American Medical Informatics Association, *5*, 467–483.

Ross, M., Spencer, S. J., Linardatos, L., Lam, K. C. H., & Perunovic, M. (2004). Going shopping and identifying landmarks: Does collaboration improve older people's memory? *Applied Cognitive Psychology*, *18*, 683–696.

Salas, E., Dickinson, T. L., Converse, S. A., & Tannenbaum, S. I. (1992). Toward an understanding of team performance and training. In R. W. Swezey & E. Salas (Eds.), *Teams: Their training and performance* (pp. 3–29). Norwood, NJ: Ablex.

Salthouse, T. A., & Babcock, R. (1991). Decomposing adult age differences in working memory. *Developmental Psychology*, *27*, 763–776.

Schriver, A. T., Morrow, D. G., Wickens, C. D., & Talleur, D. A. (2008). Expertise differences in attentional strategies related to pilot decision making. *Proceedings of the Human Factors and Ergonomics Society 52nd Annual Meeting.* Santa Monica: Human Factors & Ergonomics Society.

Shanteau, J. (1992). How much information does an expert use? Is it relevant? *Acta Psychologica*, *81*, 75–86.

Sherman, P. J. (2003). Applying crew resource management theory and methods to the operational environment. In P. S. Tsang & M. A. Vidulich (Eds.), *Principles and practice of aviation psychology.* Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

Shipley, W. C. (1946). *Institute of living scale.* Los Angeles: Western Psychological Services.

Steiner, I. E. (1972). *Group processes and productivity.* New York: Academic Press.

Vicente, K. J., & Wang, J. H. (1998). An ecological theory of expertise effects in memory recall. *Psychological Review*, *105*, 33–57.

Wegner, D. M., Erber, R., & Raymond, P. (1991). Transactive memory in close relationships. *Journal of Personality and Social Psychology*, *61*, 923–929.

Weldon, M. S., & Bellinger, K. D. (1997). Collective memory: Collaborative and individual processes in remembering. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *23*, 1160–1175.

Wiley, J., & Jolly, C. (2003). When two heads are better than one expert. *Proceedings of the Twenty-Fifth Annual Conference of the Cognitive Science Society.* Mahwah, NJ: Lawrence Erlbaum Associates Inc.

Wright, D. B. (2007). Calculating nominal group statistics in collaboration studies. *Behavior Research Methods, 39*, 460–470.

Wright, D. B., & Klumpp, A. (2004). Collaborative inhibition is due to the product, not the process, of recalling in groups. *Psychonomic Bulletin & Review*, *11*, 1081–1083.

Appendix A

Appendix: Sample Aviation Problem

DEPARTURE AIRPORT: London, Heathrow
DESTINATION AIRPORT: O'Hare Chicago
CURRENT POSITION: 70 mi E of O'Hare
AIRCRAFT ALTITUDE: FL 220
TIME OF DAY: 2:50 PM CST
GROUND TEMPERATURE: 92 degrees F
WIND CONDITIONS: Variable 5-10 kts
DESTINATION AIRPORT CONDS: Squall line approaching 10 mi W
DESTINATION RUNWAY: 27L; 10141' long; Dry
ALTERNATE: (landing) St. Louis
AIRCRAFT: Heavy twin-engine intercontinental jet

You and your crew left London, England hours ago nonstop Chicago. On your North Atlantic track midway, the number two generator fails. You start up the APU generator and continue as normal. Your dispatcher just called and added Detroit and Cincinnati to your alternate because they also have the mandatory customs and immigration facilities. Your Co-pilot lives in Indianapolis and mentions that there is a customs facility there also. You are now receiving a clearance to St. Louis calling for a rapid descent to FL 180. The Co-pilot is talking with a dispatcher who is becoming skeptical of weather in St. Louis because of the south end of the squall line nearby. At that moment, there are some blinking lights overhead and you notice the APU has auto shutdown. As you come back off the power while descending, the remaining generator has picked up the electrical load. You and your Co-pilot agree there is only an hour and ten minutes plus fuel reserve left.