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EXPLORING THE COSTS AND BENEFITS OF COLLABORATION

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Abstract

When people are asked to recall an event on multiple occasions (e.g., comparing the details reported in an initial eyewitness interview to what an eyewitness later reports at trial), it is likely that discrepancies in recall occur. Over the course of multiple recall attempts, reminisced details are often reported, and prior research shows that these details are as likely to be accurate as details recalled consistently. But no research has examined the impact of collaboration on reminiscing. This is an important question because it is common for a crime to be seen by multiple witnesses. The goal of Experiment 1 is to examine how collaboration impacts recall consistency and reminiscing. Participants viewed 40 objects arranged on a table for five minutes. Participants either Individually completed four recall tests (IIII) or recalled once Individually, Collaborated once, and then completed two more Individual recall tests (ICII). The results revealed that the IIII condition reminisced more on test 3 and had higher accuracy in the objects they reminisced compared to the ICII condition. In other words, collaboration harmed the reminisce process. Experiment 2 used a video stimulus and found, on test 3, that the collaboration (ICII) condition reminisced more details and had higher accuracy in those details than the IIII condition. Two possibilities that can explain these differing results are that the Experiment 2 stimulus was an event that had a narrative making it easier to remember and there were more opportunities to reminisce since a video has more moving parts compared to the objects in Experiment 2.

Examining How Collaborative Remembering Impacts Consistency in Recall

Eyewitnesses often are asked to recall an event on multiple occasions. When a witness tries recalling a second or third time, they may recall details they failed to mention the first time; those details that were not reported initially are referred to as reminisced details. As a witness, when you take the stand it is your legal obligation to swear an oath: a promise to "tell the truth, the whole truth, and nothing but the truth." The *whole truth* requests that you won't leave information out; the completeness of the story matters (i.e., the number of correct details recalled); whereas *nothing but the truth* puts the focus on the accuracy of what is reported (i.e., don't report things that are possibly incorrect). Much of what we recall from one attempt to another is correct and is recalled reliably. I will refer to these as *Consistent* details, details that were stated originally and are continuously recalled. Inconsistent recall, on the other hand, can take several forms. For example, *Reminiscing* occurs when details are reported that were not originally recalled, *Intrusions* occur by reporting a detail that was not originally viewed or studied, and *Forgetting* occurs when a detail reported at one time is subsequently not recalled.

Stanley and Benjamin (2016) made the important point that in a courtroom, reminisced details can make a witness seem unreliable, because lawyers view these inconsistencies in memory recall as evidence that a witness is not credible. This is often done by using prior inconsistent statements made by the witness that contradict that witness' testimony at trial (Alavi & Ahmad, 2002). Lawyers are trained to attack these inconsistencies and are skilled in doing so, even specifically asking a witness if they have inconsistencies in their statement (e.g., Has your testimony changed since your first statement?) (Alavi & Ahmad, 2002). The answer to these types of questions can make a witness appear unreliable. Consequently, reminiscing details can be seen as a red flag because newly remembered details become discrepancies that don't match

what a witness said initially. In addition, some states (e.g., Florida) explicitly instruct jurors to decide the credibility of each witness by considering their inconsistencies, and provides jurors with lists of questions they should consider ("Ask yourself if the witness testified inconsistently on the witness stand, or if the witness said or did something (or failed to say something) at any given time that is inconsistent with what the witness said while testifying," Six Circuit Criminal Pattern Jury Instructions, 2019). However, previous research has indicated that inconsistencies in memory are common and should not be seen as a signal that a person's memory is unreliable (Gilbert & Fisher, 2006; Krix, Sauerland, Lorei, & Rispens, 2015; Stanley & Benjamin, 2016).

Research shows that reminisced memories are a normal occurrence both when individuals remember on their own or with others. Other literature has shown that witnesses often remember an event together with other witnesses. What is not clear is whether remembering with others leads individuals to reminisce more and how collaborating impacts the accuracy of what is reported. We begin by reviewing 1) what is known about reminiscence, 2) the opposing views regarding whether co-witnesses discussing amongst themselves is harmful or beneficial to memory, 3) analyze how collaborative memory has been studied and review findings that indicate that collaboration can boost reminiscing on later tests, and 4) finish by discussing how memory can be measured both by how much is remembered (referencing the *whole truth* in the sworn oath) and by the accuracy of the memories recalled (referencing the *nothing but the truth* portion of the oath).

Reminisced Memories

Several studies have identified reminiscence as a common phenomenon. Gilbert and Fisher (2006) manipulated the retrieval cues across witness interviews to examine how this impacts reminiscence over two time points. This was done by having participants view a bank

robbery video and then instructing them to write a detailed statement (Time 1). They were instructed to either write down everything they could remember (free recall) or they were asked to think about the crime they just witnessed according to one of four prompted options (chronological order, reverse order, adopt the police officer's perspective, or adopt the robber's perspective), using that prompt to explain the crime from the given perspective. Two days later (Time 2), participants returned to the laboratory and were asked again to freely recall the crime or told to describe it using one of the perspectives previously mentioned. Gilbert and Fisher (2006) reported that 98% of their participants recalled at least two reminisced details and found that changing retrieval cues between test 1 and test 2 increased an individual's amount of reminiscence.

Stanley and Benjamin (2016) examined reminiscence to understand the relationship between consistency and accuracy in recall. They found that consistently recalled items were more accurate than reminisced and forgotten items. But importantly, items that were reminisced were found to be just as accurate as items that were forgotten (initially recalled but subsequently not reported). However, they did find that individuals who had more inconsistencies overall were likely to be less accurate in their overall recall. These findings suggest that inconsistencies in recall are not unusual but that reminisced details may not be too different from normally forgotten items.

Similar to Stanley and Benjamin (2016), a study by Krix et al. (2015) that had participants view a theft video also found that reminisced and forgotten details had comparable levels of accuracy. Their overall results again supported the notion that reminiscing is a common occurrence; every participant had reminisced information. However, they found that the amount of reminiscence was not an indicator of overall accuracy, which suggests that witnesses should

not be discredited just because they reminisce details. Krix et al. (2015) also included an additional interesting element, an estimation group that consisted of police detectives who estimated the eyewitness's overall accuracy across Time 1 and Time 2. The estimation group (the police officers) rated the reminisced details as being less accurate compared to consistent details. The officers were asked to justify why they rated reminisced details as being either accurate or inaccurate. The top two reasons for assigning low accuracy to reminisced details was: 1) new information was suggestive of external influence, 2) the witness filled the gaps of the event in order to have a complete story. Moreover, although actual accuracy remained stable across both tests for the two memory groups, the estimation group believed that accuracy would decline on the second test (Krix et al., 2015). These results indicate that there are misconceptions regarding beliefs about recall consistency among police detectives that are contrary to actual recall performance. The police also routinely instruct witnesses not to speak to one another. Is this also a misconception; are police making the right call to avoid so-called co-witness effects?

Co-Witness Effects

Often times, an eyewitness recalls an event with multiple witnesses. Skagerberg and Wright (2008) examined sixty real co-witnesses from the Force Identification Unit in Brighton (UK). They reported that 88% of their sample had witnessed a crime with at least one other witness, and 58% of the witnesses had discussed the event with a co-witness. Studies have shown that when co-witnesses communicate, there may be "contamination" amongst one another's memory (Gabbert, Memon, & Allan, 2003; Loftus, 2003; Shaw, Garven, & Wood, 1997). Gabbert et al. (2003) showed pairs of participants a crime video. Each individual saw a different perspective of the video; however, they were led to believe that they both saw the same video. Participants then either had a memory discussion with another witness who viewed a

different perspective or did a memory rehearsal on their own. Lastly, an individual recall test was completed by each participant. They found that 60% of the participants in the co-witness condition reported information that they had personally not witnessed. Furthermore, many of the items reported were obtained from the memory discussion with the co-witness (Gabbert et al., 2003). In another set of studies, Shaw et al. (1997; Study 2 & 3) had participants watch a robbery video and then questioned pairs (one participant and a confederate) about the event. The pair took turns answering questions about the crime and the confederate would sometimes state incorrect information. In both experiments, they found that when the participant had heard an incorrect answer from the co-witness "confederate" before they gave an answer, participants were more likely to give the incorrect answer they had just heard from the co-witness.

Paterson and Kemp (2005) surveyed police officers and found that the common protocol was to keep the witnesses from communicating with each other, but many police officers stated that they believed that allowing co-witnesses to communicate came with some benefits. Specifically, when co-witnesses communicate, the discussion can cue a witness to remember details not remembered earlier (Paterson & Kemp, 2005). Warnick and Sanders (1980) had participants watch a video of a crime and then either work alone, or in small groups, in order to recall the crime. Some of the groups were asked to reach unanimous decisions whereas others were not. They found that group discussion, both with and without consensus decisions, led to significantly increased overall accuracy compared to individuals recalling alone. Groups also were superior to individuals when it came to the completeness of the crime reports (Warnick & Sanders, 1980). In sum, the literature is inconclusive regarding whether co-witness discussions are harmful or helpful. Perhaps the broader literature on collaboration can shed light on the costs and benefits of remembering with a partner.

Collaborative Memory

A lot of research has focused on individuals remembering alone, but we often retrieve and reconstruct memories with others. To study how collaboration impacts memory, participants recall stimuli either alone or in collaboration with another participant (Basden, Basden, & Henry, 2000; Weldon & Bellinger, 1997). Pair performance is then compared to nominal groups (i.e., pooling the original scores of two or more individuals but counting their redundant items only once). Collaborative groups tend to recall less than nominal groups, a phenomenon referred to as collaborative inhibition (Weldon & Bellinger, 1997). The most commonly cited cognitive mechanism thought to explain collaborative inhibition is the retrieval-strategy disruption hypothesis (Basden, Basden, Bryner, & Thomas, 1997). This hypothesis proposes that individuals use strategies to organize newly learned information that are unique to each individual; when these strategies are subsequently followed it leads to greater retrieval. However, Basden et al. (1997) suggested that when individuals are forced to collaborate, it may result in collaborative inhibition because being exposed to a different group member's responses may disrupt one's own retrieval strategy. However, studies have shown that even though information may be lost during group recall, the lost information often tends to reappear when participants are asked to subsequently recall the information on their own (Blumen & Rajaram, 2008; Finlay, Hitch, & Meudell, 2000).

But there can be both costs and benefits when individuals remember together. Weldon and Bellinger (1997) found that when participants were given a second recall test, the participants who were initially tested in Collaborative groups recalled more than the participants that were tested Individually. In comparing ICI and III conditions, Blumen and Rajaram (2008) also found that when a participant was re-exposed to the information in the collaborative

condition it led to increased recall and reminiscence on their final test. Their results suggested that allowing an individual to establish their own individual retrieval strategies prior to collaboration can lead to benefitting from the re-exposure of information during group collaboration, which in turn improves recall when the individual is tested alone. Some have argued that a potential benefit of collaborative groups is that they tend to recall fewer errors (Harris, Barnier, & Sutton, 2013). This is thought to occur because group members may recognize, and prune out, each other's errors (Rajaram & Pereira-Pasarin, 2010; Ross, Spencer, Blatz, & Restorick, 2008). However, it is important to note that not all errors are pruned out. Occasionally, when an individual makes an error, the group members do not realize the error, leading this error to "contaminating" their group's memory. This is known as social contagion of memory errors (Meade & Roediger, 2002; Roediger, Meade, & Bergman, 2001). When a free-flowing method of collaboration is used, this leads to fewer memory errors because participants can interact freely and more readily correct one another. Conversely, when a turn-taking procedure is used, participants cannot discuss possible errors and intrusions are more likely to occur (Rajaram & Pereira-Pasarin, 2010).

In sum, our first issue of interest is to identify how collaboration affects recall consistency. We hypothesize that recalling with a partner will enhance the ability to reminisce details on future tests. Because test one is done individually, we assume that individuals structure their own unique strategies, but they have an opportunity to be re-exposed to this information when they collaborate on test two, which together will lead them to reminisce items they previously had not remembered.

We next introduce how memory has been traditionally studied, with an emphasis on the amount that is remembered (input-bound accuracy), and then discuss how to measure memory to

highlight the accuracy of what is recalled (output-bound accuracy). These two measures will allow us to assess, respectively, the whole truth and nothing but the truth.

Accuracy of Memory

Historically, memory research has focused on the amount of information that is recalled. Koriat and Goldsmith (1996) referred to this as the storehouse metaphor of memory, which conceptualized memory as "something that can be counted." According to the storehouse metaphor, memory is a structure where memory items are deposited and later retrieved (Koriat & Goldsmith, 1996a). The venerable list-learning paradigm follows from this metaphor: participants learn a list of words, then later retrieve the words, with participants' memory evaluated by the amount of recalled words (Koriat & Goldsmith, 1996a). The storehouse metaphor is a quantity-oriented approach focusing on *how much* is recovered (an assessment of the *whole truth*). Quantity-based measures are referred to as input-bound because they assess the chances that an input stimulus will be reproduced (Koriat & Goldsmith, 1994). According to the storehouse metaphor, participants are held accountable for what they *fail* to report (i.e., what they forgot). Even though the storehouse metaphor has resulted in important research revealing factors that affect how much can be remembered, Koriat and Goldsmith (1996a) propose that how much an individual can recall matters little in day-to-day situations.

Koriat and Goldsmith (1996) also referenced a correspondence metaphor that conceptualized memory "as something that can be counted on" (p.3). The key here is the degree of correspondence between what is reported and what actually occurred (Koriat & Goldsmith, 1994). According to the correspondence metaphor, the key aspect of performance is referred to as output-bound accuracy (an assessment of *nothing but the truth*); it reflects the likelihood that each reported item of information is correct (Koriat & Goldsmith, 1996a). In this approach,

accuracy is assessed based only on what an individual recalls, not by what they forget (Koriat & Goldsmith, 1994).

In sum, our second issue of interest is how the output-bound accuracy of reminisced memories changes after multiple recall attempts, as well as identifying how collaboration impacts a person's output-bound accuracy. We predict that collaborating will not adversely impact the output-bound accuracy of reminisces.

Both studies set out to understand how collaboration impacts the accuracy memory, specifically looking at the accuracy of consistent, reminisced, and forgotten details. The literature surrounding collaboration and reminisced details in particular is scarce and both studies aimed to understand more about this phenomenon.

Experiment 1

Method

Participants

Participants were 96 undergraduate students at the University of Oklahoma participating in exchange for SONA credit. There were 71 females and 25 males (M = 19.05, SD = 1.04). All participants gave written consent and were debriefed following the completion of the study.

Design

The IIII AND ICII (I corresponds to individual recall and C corresponds to collaborative recall) conditions were varied according to a between-subject design. There were 40 participants in the IIII condition; there were 28 pairs in the ICII condition. Participants in the IIII condition were later randomly assigned to nominal groups creating 20 pairs.

Materials

The stimuli included 40 random objects arranged on a table. All objects were items that were easy to name (cheese grater, envelope, battery, etc.). A number search was used as a distractor task after the study phase and in-between each of the recall tests.

Procedure

Prior to arriving, participants were randomly assigned to either the individual or the collaborative condition. Participants were brought into a room and instructed that they would be taken into another room to view 40 random objects; their task would be to study the objects for 5 minutes. They were notified that they would later be tested on their memory of the objects. Participants were told that they could touch the objects but must refrain from talking. After the study phase, participants were taken into another room where they completed four 5-minute recall tests with a 3-minute distraction task in between each test (see Figure 1). Participants were encouraged to try to remember for the entire time because the experiment would not continue until the entire 5-minute recall period elapsed.

Participants in the individual condition were tested four times alone (denoted IIII). Participants in the collaborative condition were tested alone for test 1, and then collaborated on test 2. The pair was instructed to work with their partner to remember as many of the objects from the table. One of the participants was randomly assigned to be the writer for the test. Participants were told that they should both come to an agreement about remembering an object before the writer wrote down the object. These two individuals then recalled individually two more times (denoted ICII).

Results

The data from each collaborative and individual recall were classified based on whether the object was consistent, forgotten, reminisced, or an intrusion. Table 1 illustrates the

definitions of these different classifications. A consistently recalled object was one that was reported beginning on test one. A forgotten object was reported, but then not reported on a subsequent test. An object not reported a second time was still classified as forgotten. A reminisced object was not reported but was then later remembered; this designation was independent of when or how many times this occurred. For example, if an object was reminisced, and then reported again, subsequently this object would be considered part of a participant's recall. Conversely, if the reminisced object is subsequently forgotten but then reported again later, it would be counted as reminisced. Lastly, intrusions were objects that were reported but were not originally studied. The output-bound accuracy scores, for both the IIII and ICII conditions, were computed for the consistent, reminisced, and forgotten classifications.

Our main goals in this study are to identify how collaboration impacts consistency in recall and how accurate reminisced memories are after multiple recall attempts. We will first examine the input-bound accuracy followed by the output-bound accuracy of consistent, reminisced and forgotten memories, for both the IIII and ICIII conditions. Then we will examine the findings regarding the collaborative inhibition effect. To examine collaborative inhibition, the scores from the individual condition will be used to create a paired nominal condition for the evaluation of test 2 (the collaborative test in the ICII condition). This is done by pooling the reports of two individuals but only counting their redundant objects once (Weldon & Bellinger, 1997). This technique creates a fair comparison of the collaborative condition to another "paired condition." The nominal conditions for tests 3 and 4 were not pooled. [1]

Consistent

[1] In order to reduce the family-wise error rate, alpha was adjusted by dividing by the number of tests when multiple comparisons were made.

To examine how collaboration affected consistent recall, a 2 (condition: individual vs. collaborative) X 2 (tests: test 3 vs. test 4) mixed ANOVA was conducted. It revealed no significant interaction between condition and test $F(1, 93) = .489$, $p = .243$, $\eta_p^2 = .005$. The main effect for condition also was not significant, $F(1, 93) = .359$, $p = .276$, $\eta_p^2 = .004$. However, a significant main effect of test was obtained, $F(1, 93) = 89.22$, $p = .000$, $\eta_p^2 = .490$. Bonferroni-adjusted comparisons indicated that .95 more objects were consistently recalled during test 3 than test 4 ($p = .000$, 95% *CI* of the difference = .749 to 1.148). The amount of consistent recalled objects in test 3 ($M = 19.20$, $SD = 5.68$) was higher than test 4 ($M = 18.24$, $SD = 5.68$).

Reminiscence

To examine the likelihood of reminiscing after collaboration, a 2 (condition: individual vs. collaborative) X 2 (tests: test 3 vs. test 4) mixed ANOVA revealed that the main effect for condition was not significant, $F(1, 93) = .490$, $p = .243$, $\eta_p^2 = .005$. However, a significant main effect of test was obtained, $F(1, 93) = 18.30$, $p = .000$, $\eta_p^2 = .164$, as well as a significant interaction between test and condition, $F(1, 93) = 7.24$, $p = .004$, $\eta_p^2 = .072$ (see left side of Figure 2). Bonferroni-adjusted comparisons indicated during test 3 the individual condition reminisced .705 more than the collaborative condition ($p = .031$, 95% *CI* of the difference = .068 to 1.343). However, during test 4 the conditions varied by .425, which was not a significant difference ($p = .099$, 95% *CI* of the difference = -.082 to .932). These findings indicate that previously collaborating with a partner inhibited a participant's ability to reminisce on test 3 but not test 4.

Forgotten

To examine how collaboration impacted forgotten items, a 2 (condition: individual vs. collaborative) X 2 (tests: test 3 vs. test 4) mixed ANOVA revealed that the main effect for

condition was significant, $F(1, 93) = 31.23$, $p = .000$, $\eta_p^2 = .251$, as was the effect of test, $F(1, 93) = 42.62$, $p = .000$, $\eta_p^2 = .314$ (see right left of Figure 5). . The interaction between condition and tests was non-significant, $F(1,93) = .253$, $p = .308$, $\eta_p^2 = .003$. Bonferroni-adjusted comparisons indicated that there were 1.427 more forgotten objects during test 4 than test 3 ($p = .000$, 95% *CI* of the difference = .993 to 1.861) and the collaborative condition forgot 2.871 more objects than the alone condition ($p = .000$, 95% *CI* of the difference = 1.851 to 3.891). For both test 3 and 4, those in the individual condition forgot significantly fewer objects than those in the collaborative condition. It is likely that those in the collaborative condition forgot more because participants forgot some of the objects mentioned by their partner in test 2.

Intrusions

To examine how often intrusions occurred, a 2 (condition: individual vs. collaborative) X 2 (tests: test 3 vs. test 4) mixed ANOVA revealed that the main effect for condition was not significant a, $F(1, 93) = .091$, $p = .382$, $\eta_p^2 = .001$. There was no main effect of test, $F(1, 93) = .469$, $p = .247$, $\eta_p^2 = .005$ and no significant interaction between condition and test, $F(1, 93) = .1.37$, $p = .121$, $\eta_p^2 = .015$. For test 3, the individual condition ($M = .60$, $SD = 1.02$) had about the same number of intrusions as collaborative ($M = .50$, $SD = .77$); test 4 had similar results, individuals ($M = .58$, $SD = .80$), collaboration ($M = .59$, $SD = .83$). Both conditions were susceptible to intrusions, although intrusions were rare.

In sum, the recall of consistent objects was greater on test 3 than 4, but condition did not matter. However, those in the individual condition reminisced more, and forgot fewer objects, on test 3. Intrusions were rare and did not differ due to test or condition.

Input-bound Accuracy

Input-bound accuracy indicates the proportion of studied objects that are correctly reported. It is computed by dividing the number of correctly recalled objects by the number of objects originally studied. To compare the input-bound accuracy for recalled objects, a 2 (condition: individual vs. collaborative) X 2 (tests: test 3 vs. test 4) mixed ANOVA was conducted on the proportion recalled. The main effect of test was non-significant, $F(1, 93) = 2.03$, $p = .079$, $\eta_p^2 = .021$, as was the interaction between condition and test, $F(1,93) = .465$, $p = .248$, $\eta_p^2 = .005$, but the main effect for condition was significant, $F(1, 93) = 3.99$, $p = .025$, $\eta_p^2 = .041$. Bonferroni-adjusted comparisons indicated that the input-bound accuracy was .056 higher for the collaborative condition compared to the individual condition ($p = .049$, 95% *CI* of the difference = .000 to .112). This may be due to participants in the collaborative condition incorporating objects that they had just previously recalled with their partner on test 2. When objects were reminisced with a partner on test 2, these same objects, if reported on test 3, will not be classified as reminisced, which explains the greater proportions of recalled objects for the collaborative condition. To better understand how the recalls from the different classifications fit together, Table 2 shows the frequencies for consistent, reminisced, and forgotten objects, intrusions and the total recalled (i.e., all the studied items recalled by the participant). The differences between the total recalled for the collaborative and individual conditions are easily identifiable in Table 2.

Output-bound Accuracy of Consistent

Output-bound accuracy indicates the proportion of reported objects that are correct. It is computed by dividing the number of correctly recalled objects by the total amount of objects recalled. To compare the output-bound accuracy for consistent objects, a 2 (condition: individual vs. collaborative) X 2 (tests: test 3 vs. test 4) mixed ANOVA revealed no significant effects (main effect for condition, $F(1, 93) = 2.48$, $p = .06$, $\eta_p^2 = .026$, main effect for test $F(1, 93) =$

.175, p = .338, η_p^2 = .002, and the interaction, $F(1,93)$ = 2.06, p = .078, η_p^2 = .022). These insignificant results are due to a ceiling effect: the output-bound accuracy of consistent objects did not differ in the individual condition on test 3 (M = .98, SD = .03) or test 4 (M = .98, SD = .03). Similar results were found in the collaborative condition in test 3 (M = .98, SD = .02) and test 4 (M = .99, SD = .03). These results are summarized in Table 3.

Output-bound Accuracy of Reminisced Objects

To compare the output-bound accuracy for reminisced memories, a 2 (condition: individual vs. collaborative) X 2 (tests: test 3 vs. test 4) mixed ANOVA revealed that the main effect for condition was not significant, F(l, 93) = .159, p = .346, η_p^2 = .002. However, there was a significant main effect of test, F(l, 93) = 9.71, p = .001, η_p^2 = .095, and a significant interaction, F(l, 93) = 6.80, p = .005, η_p^2 = .068 (the left side of Figure 3). Bonferroni-adjusted comparisons indicated that there was a .34 mean difference from test 3 to test 4 for the individual condition (p = .000, 95% CI of the difference = .16 to .52): test 3 (M = .85, SD = .06) had greater accuracy for reminisced objects compared to test 4 (M = .51, SD = .08). As for the collaborative condition, there was a .03 mean difference from test 3 to test 4 (p = .699, 95% CI of the difference = -.12 to .19), and no significant difference in the accuracy of reminisced objects for test 3 (M = .66, SD = .06) and test 4 (M = .63, SD = .07). Taken together, these results indicate that being in the individual condition led to higher output-bound accuracy of reminisced objects for test 3, but not for test 4.

Output-bound Accuracy of Forgotten Objects

To examine the output-bound accuracy for forgotten objects, a 2 (condition: individual vs. collaborative) X 2 (tests: test 3 vs. test 4) mixed ANOVA revealed that the main effect for condition was significant, F(l, 93) = 32.91, p = .000, η_p^2 = .261, a significant main effect of test

was also obtained, $F(1, 93) = 24.67$, $p = .000$, $\eta_p^2 = .210$, as was a significant interaction, $F(1, 93) = 8.11$, $p = .005$, $\eta_p^2 = .080$ (see Figure 4). Participants in the collaborative condition had significantly higher output-bound accuracy for forgotten objects, especially on test 3. Bonferroni-adjusted comparisons indicated that for the individual condition, there was a .31 mean difference from test 3 to test 4 ($p = .000$, 95% *CI* of the difference = .19 to .43); during test 3 ($M = .52$, $SD = .06$), the output-bound accuracy of forgotten objects was lower compared to test 4 ($M = .83$, $SD = .04$).

In sum, the output-bound accuracy for consistent objects did not differ by test or condition; objects that were consistently recalled had 98% or higher output-bound accuracy. Reminisced objects had a greater output-bound accuracy for the individual condition compared to the collaborative condition, but only for test 3. Forgotten objects had greater output-bound accuracy for the collaborative condition on tests 3 and 4 compared to the individual condition.

Discussion

The current study revealed that collaboration during recall results in both costs and benefits. On test 3, we found that collaborating led to less reminiscing compared to those who recalled individually, and that the output-bound accuracy of reminisced objects after collaboration tended to be less accurate than those who recalled alone. However, those who collaborated had a greater total recall on subsequent tests compared to those who recalled alone. We next will review these costs and benefits and then describe an alternative scenario to better highlight the impacts of collaboration.

Individuals reminisced regardless of whether they were in the IIII or ICII condition. But contrary to our prediction, the IIII participants reminisced more on test 3 than the ICII. Basden et al. (2000) found similar results when they conducted studies with multiple study-test cycles and

had participants free-recall a list of words twice together and then conducted the final recall test individually. We had expected that collaborating on test 2 would re-expose studied objects to participants in the collaborative condition, and thereby enhance their ability to reminisce items not reported on test 1. However, this was not the case for test 3; collaboration induced a cost on reminiscing. Meudell, Hitch, & Kirby, (1992) also found similar findings.

But collaboration induced a benefit on overall recall. The number of total recalled objects on test 3 and test 4 were greater for the collaborative condition than the individual condition (see Table 2). These results replicated Harris, Barnier, & Sutton (2012); Rajaram & Pereira-Pasarin, (2010); prior collaboration led to increased recall on subsequent individual tests. This is interesting because the reduced reminiscing induced by collaboration signals that the greater total recall is not due to additional *new* objects being reminisced. So where are the extra recalled objects coming from in the collaboration condition? Weldon and Bellinger (1997) suggested that these extra details may arise from being re-exposed during the collaborative test, which then makes them more accessible during later retrievals. Apparently, the collaborative test (test 2) re-exposed objects from one member of a pair to their partner. These extra re-exposed objects, which cannot be reminisced because they were reported on test 2, increased the total recalled. All and all, when participants who collaborated are asked to subsequently recall alone (on tests 3 and 4), the re-exposed objects that were brought up with their partner become more accessible to them in later tests, compared to participants in the individual condition, who had to rely on trying to reminisce objects not presented since the initial study phase.

During test 3, there was a large discrepancy between the output-bound accuracy of forgotten objects for the individual and collaborative condition. The collaborative condition had greater output-bound accuracy due to the prior collaborative test (test 2). Test 2 had the highest

level of recall for the collaborative condition. Then, on test 3, individuals in the paired condition often forgot some of the objects they had previously recalled with their partner. This explains why the output-bound accuracy was high, because working with a partner likely resulted in pruning out errors in test 2. However, participants were not able to remember all of the new objects on test 3 on their own. It also appears that 50% of the objects in the individual condition that were forgotten on test 3 were intrusions, suggesting that the individuals were reconsidering objects that they had erroneously recalled.

Taken together, there are both benefits and costs to collaboration. Prior collaboration led to greater recall on subsequent individual tests, but collaborating negatively impacted the ability to reminisce original study objects on later individual tests. One shortcoming of Experiment 1 is that every object was equally salient. In real-life, some details are more important than others. The consideration of a real-life scenario can help highlight additional aspects of the costs and benefits of collaboration. For example, suppose two witnesses experience a crime. The results from Experiment 1 suggest that reminisced details are less likely if these co-witnesses communicate with one another compared to if each witness recalled on his or her own. But on the plus side, witnesses who collaborate are able to recall a greater number of details when they are asked to remember again on their own (compared to individuals who remember independently). Although it is important to have the complete story about a crime and what occurred, it is also clear that reminiscing (reporting new details) happens to both those who recall alone and those who collaborate. Therefore, to understand more about how collaboration impacts reminisced details, research is needed using a more complex stimulus event to see if *what* is reminisced is impacted by collaboration. For example, collaboration, despite reducing reminiscing overall, may enhance reminiscing of key details because if an event follows a

storyline, remembering is driven by the details that drive the story (Alba & Hasher, 1983). An exploration of this issue is the primary goal of Experiment 2.

Experiment 1 showed that collaboration harmed an individual's opportunity to reminisce more than helping it, and when individuals did collaborate, their output-bound accuracy of the reminisced items following collaboration was not always as accurate as the individuals who recalled alone. The common objects used as stimuli for Experiment 1 revealed some interesting findings, but it is important to test whether the same findings occur in a situation more similar to eyewitnesses reporting on an event. If the current findings replicate, it will provide empirical support for the current protocol whereby police officers keep witnesses apart so that they do not communicate prior to being interviewed.

Experiment 2

Hypotheses

Experiment 2 will use a video that has a narrative. Schema theory is often relied upon when examining how we recall an event or story (Alba & Hasher, 1983; Bartlett, 1932). Schemas are knowledge structures that serve to complete an entire story by filling in gaps while organizing and prioritizing the elements of the event by their importance (Alba & Hasher, 1983). Because of the influence of schemas, we predict that the collaborative condition will have more reminisced details than in Experiment 1 because the organizational structure provided by a scheme provides more opportunities to reminisce than from the static objects used in Experiment 1.

This use of a video narrative in Experiment 2 also allows for the opportunity to sort the type of information recalled. That is, there are both *key* and *minor* details that may be retrieved. This leads us to our next hypothesis: Those in the collaborative condition will reminisce more

minor details. An event has a narrative structure. Considering the retrieval strategy disruption hypothesis (Basden et al., 1997), individuals may organize and retrieve random objects in a variety of ways, but it seems logical to infer that when you consider the retrieval of an actual event, the common narrative structure makes it likely that individuals will utilize similar retrieval strategies. Consequently, it makes sense that two people collaborating would focus attention on the key details that drove the narrative rather than the minor details. Remembering key details that give meaning to the story are often remembered due to their importance in constructing the narrative (Alba & Hasher, 1983). Establishing this strong memory understanding of the key details may lead to these key detail memories being reported earlier in the recall period. Consequently, co-remembering key details on test 2 will help participants reminisce more minor details on subsequent tests because memory for a narrative is squared away.

We also will examine the output-bound accuracy of the consistent details, where accuracy should again be very high, as it was in Experiment 1. However, we expect to see more intrusions in Experiment 2 because the switch to an event that carries a narrative will lead individuals to make inferences and fill-in gaps when necessary (Alba & Hasher, 1983; Loftus, 2003). But those in the collaborative condition will have fewer intrusions compared to the individual condition because working with a partner will prune out errors (Rajaram & Pereira-Pasarin, 2010). The output-bound accuracy in the collaborative condition will benefit from fewer intrusions.

Method

Participants

A statistical power analysis using GPower was performed for sample size estimation, based on the data from Experiment 1. The projected sample size was $N = 126$ people in order to

have .8 power to detect a medium effect size. Participants were 143 undergraduate students at the University of Oklahoma participating in exchange for SONA credit. The achieved power for this sample was .84 to detect a medium effect size. There were 97 females and 46 males (M = 18.78, SD = 2.00). All participants gave written consent and were debriefed following the completion of the study.

Design

The study design is the same as Experiment 1: IIII AND ICII conditions in a between-subject design. There were 47 participants in the IIII condition; there were 48 pairs in the ICII condition. Participants in the IIII condition were later randomly assigned to nominal groups creating 23 nominal pairs.

Materials

The stimulus is an 8-minute clip from the movie *Looking for Miracles* (Sullivan, 1989). The video depicts the adventures of two brothers at summer camp. A number search will be used as a distractor task after the study phase and in-between each of the recall tests (see Figure 1).

Procedure

The procedure has a similar format to Experiment 1 except instead of viewing objects the participants watched a movie segment. Prior to beginning the study, participants were randomly assigned to either the individual or the collaborative condition. Originally, this study was to take place in-person, however, due to Covid-19 restrictions, all sessions were collected via Zoom.

Participants joined a live Zoom meeting and were asked to turn on and have their cameras on for the entire study with their faces visible. The research assistant also had their camera on the entire time and was logged on during the duration of the entire study in case the participants had questions and to orchestrate the condition. Participants were then instructed by

the research assistant to watch an 8-minute video clip and informed that they should study the video carefully because their memory of the video would be tested. After watching the video, participants were instructed that they would complete four recall tests with a 3-minute distraction task between each test, all data was collected using Qualtrics.

Rather than remembering all of the details from the video at once, recall was broken down based on the three scenes in the video. During the recall tests, participants were prompted with the scene of the video from which they should remember. For example, "The first scene took place in the dining hall. Please discuss what events occurred, who was in the scene, describe the people who were there and any other details you can remember, such as important conversations that happened." Participants were then required to spend four minutes on each section for a total of 12 minutes across the three testing periods. Participants were encouraged to try to remember for the entire time because the experiment would not continue until each 4-minute recall period elapsed.

Scoring of the recall was subdivided by whether the reported details were key, minor, or extra details. A pilot study was completed in order to operationalize key versus minor details. Eleven participants viewed the video clip. In contrast to how things proceeded in the experiment, the pilot participants recalled after viewing each of the three scenes rather than after viewing the entire video. Key details were details that were reported in the pilot study at least 6 to 10 times amongst the participants and minor details were reported between 2-5 times amongst the participants. When scoring the data, a category called extra details was added that consisted of recalled details that were correct, judged relevant, but not already categorized as a key or minor detail. Table 7 lists all key and minor details that were included in Experiment 2 along with a couple example details that were considered extra details.

Participants in the individual condition were tested four times alone (IIII). Participants in the collaborative condition were tested alone for test 1, and then collaborated on test 2. The pair was instructed to work with their partner to remember as many details from the three sections of the video. One of the participants was randomly assigned to be the writer. Participants were told that they must come to an agreement about remembering a detail before the writer typed it down into Qualtrics. These two individuals then recalled individually two more times (ICII).

Twenty-three of the forty-eight collaborative tests were video recorded via Zoom. This was done to examine how the pairs worked together. We were interested in learning more about how the pairs decide about including, or not including, details in their recall, whether the writer or other participant contributes more to the group recall, and any strategies the pairs used when collaborating.

Results

Examining Collaborative Reminisced Key and Minor Details

To compare how key and minor details varied between test 3 and test 4 for the collaborative condition, a 2 (tests: test 3 vs. test 4) X 2(detail types: key vs minor) repeated-measures ANOVA revealed a significant main effect for detail type $F(1, 95) = 67.26$, $p = .000$, $\eta_p^2 = .415$. However, both the main effect for test, $F(1, 95) = 3.72$, $p = .057$, $\eta_p^2 = .038$, and the interaction, $F(1, 95) = 2.36$, $p = .127$, $\eta_p^2 = .024$, were non-significant. There were more reminisced minor details ($M = 2.34$, $SD = 2.51$) compared to key details ($M = 1.99$, $SD = 2.00$). Table 5 categorizes the type of details by key, minor, and extra, and includes the frequencies by the type of memory (consistent, reminisced, and forgotten).

Consistent

To examine how collaboration affected consistent recall, a 2 (condition: individual vs. collaborative) X 2 (tests: test 3 vs. test 4) mixed ANOVA was conducted. It revealed no significant interaction between condition and test $F(1, 131) = 1.03$, $p = .157$, $\eta_p^2 = .007$. The main effect for condition also was not significant, $F(1, 131) = .081$, $p = .388$, $\eta_p^2 = .001$. However, a significant main effect of test was obtained, $F(1, 139) = 22.77$, $p = .000$, $\eta_p^2 = .141$. Bonferroni-adjusted comparisons indicated that that there were .351 more consistently recalled objects during test 3 than test 4 ($p = .000$, 95% *CI* of the difference = .206 to .497). The amount of consistent recalled objects in test 3 ($M = 26.75$, $SD = 9.57$) was higher than test 4 ($M = 26.43$, $SD = 9.58$). The average frequency for consistent, reminisced, forgotten, and total recall is summarized in Table 4.

Reminiscence

To examine the likelihood of reminiscing after collaboration, a 2 (condition: individual vs. collaborative) X 2 (tests: test 3 vs. test 4) mixed ANOVA revealed that the main effect for condition was significant, $F(1, 139) = 7.11$, $p = .005$, $\eta_p^2 = .049$. A significant main effect of test was also obtained, $F(1, 139) = 82.06$, $p = .000$, $\eta_p^2 = .371$, as well as a significant interaction between test and condition, $F(1, 139) = 7.66$, $p = .003$, $\eta_p^2 = .052$ (see right side of Figure 2). Bonferroni-adjusted comparisons indicated during test 3 the collaborative condition reminisced 2.34 more details than the individual condition ($p = .003$, 95% *CI* of the difference = .810 to 3.871). However, during test 4 the conditions only varied by .074, which was not a significant difference ($p = .846$, 95% *CI* of the difference = -.681 to .830). These findings indicate that previously collaborating with a partner helped reminisce more details on test 3. These findings differ from what we found in Experiment 1.

Forgotten

The results for the mixed ANOVA for *forgotten* and *intrusions* violated the homogeneity of variance assumption and were not normally distributed. In order to address these violations, a square-root transformation was applied and successfully corrected these issues.

To examine how collaboration impacted forgotten items, a 2 (condition: individual vs. collaborative) X 2 (tests: test 3 vs. test 4) mixed ANOVA revealed that the main effect for condition was significant, $F(1, 139) = 26.62$, $p = .000$, $\eta_p^2 = .161$, and there was a significant effect of test, $F(1, 139) = 60.24$, $p = .000$, $\eta_p^2 = .302$. The interaction between condition and tests also was significant, $F(1,139) = 6.30$, $p = .007$, $\eta_p^2 = .043$ (see Figure 5, right side). Bonferroni-adjusted comparisons revealed a 4.03 mean difference between the collaborative and individual condition ($p = .000$, 95% *CI* of the difference = 2.109 to 5.955), indicating that during test 3, the collaborative condition ($M = 7.32$, $SD = 5.58$) forgot more compared to the individual condition ($M = 2.96$, $SD = 4.07$). This was also true for test 4, the collaborative condition forgot ($M = 8.66$, $SD = 6.47$) more than the individual condition ($M = 4.96$, $SD = 5.55$).

Intrusions

To examine intrusions, a 2 (condition: individual vs. collaborative) X 2 (tests: test 3 vs. test 4) mixed ANOVA revealed that the main effect for condition was non-significant, $F(1, 139) = .754$, $p = .194$, $\eta_p^2 = .005$, but there was a significant main effect of test, $F(1, 139) = 13.82$, $p = .000$, $\eta_p^2 = .090$. No significant interaction was found between condition and test, $F(1, 139) = .757$, $p = .193$, $\eta_p^2 = .005$. Although both conditions were susceptible to intrusions, intrusions were rare. There were more intrusions on Test 3 ($M = .55$ $SD = .87$) compared to test 4 ($M = .36$, $SD = .68$) (see Figure 6).

Input-bound Accuracy

The *Input-bound Accuracy* and *Output-bound Accuracy of Consistent Details* data violated the normal-distribution assumption; the *Output-bound Accuracy of Reminisced Details* and *Output-bound Accuracy of Forgotten Details* violated the homogeneity of variance assumption and the normality assumption. To address these violations, both an arcsine and logit transformation were applied to the data. However, the logit transformation only fixed the input-bound accuracy data. The transformations did not fix the violations for any of the output-bound accuracy data. Here we report the original results from the mixed ANOVAs but urge caution in interpreting the results given the violation of the homogeneity and normality assumptions.

To compare the input-bound accuracy for recalled objects, a 2 (condition: individual vs. collaborative) X 2 (tests: test 3 vs. test 4) mixed ANOVA was conducted on the proportion recalled. The main effect of test was significant, $F(1, 139) = 16.64$, $p = .000$, $\eta_p^2 = .107$. Neither the main effect for condition, $F(1, 139) = 2.52$, $p = .06$, $\eta_p^2 = .018$ nor the interaction were significant, $F(1, 139) = .092.$, $p = .381$, $\eta_p^2 = .001$. The input-bound accuracy was lower in test 3 ($M = .64$ $SD = .13$) compared to test 4 ($M = .66$, $SD = .14$).

Output-bound Accuracy of Consistent Details

To compare the output-bound accuracy for consistent objects, a 2 (condition: individual vs. collaborative) X 2 (tests: test 3 vs. test 4) mixed ANOVA revealed a significant main effect for test, $F(1, 139) = 9.50$, $p = .001$, $\eta_p^2 = .064$. The main effect for condition was nonsignificant, $F(1, 139) = .026$ $p = .436$, $\eta_p^2 = .000$, as well as the interaction, $F(1,139) = .268$, $p = .303$, $\eta_p^2 = .002$. The output-bound accuracy of consistent details was lower on test 3 ($M = .97$, $SD = .05$) compared to test 4 ($M = .98$, $SD = .04$). These results are summarized in Table 6.

Output-bound Accuracy of Reminisced Details

To compare the output-bound accuracy for reminisced memories, a 2 (condition: individual vs. collaborative) X 2 (tests: test 3 vs. test 4) mixed ANOVA revealed two significant main effects (for condition, $F(1, 139) = 5.25$, $p = .012$, $\eta_p^2 = .036$, for test $F(1, 139) = 24.11$, $p = .000$, $\eta_p^2 = .148$). However, the interaction was non-significant, $F(1,139) = 2.16$, $p = .072$, $\eta_p^2 = .015$ (see Figure 3). The output-bound accuracy of reminisced details was higher in test 4 ($M = .88$, $SD = .23$) compared to test 3 ($M = .65$, $SD = .44$). The collaborative condition had a higher output-bound accuracy compared to the individual condition.

Output-bound Accuracy of Forgotten Details

To examine the output-bound accuracy for forgotten details, a 2 (condition: individual vs. collaborative) X 2 (tests: test 3 vs. test 4) mixed ANOVA revealed that the main effect for condition was significant, $F(1, 139) = 12.45$, $p = .000$, $\eta_p^2 = .082$, a significant main effect of test was also obtained, $F(1, 139) = 27.80$, $p = .000$, $\eta_p^2 = .167$, as was a significant interaction, $F(1, 139) = 9.92$, $p = .001$, $\eta_p^2 = .067$ (see Figure 4). The results reveal that participants who were in the collaborative condition had significantly higher output-bound accuracy for forgotten details, for both test 3 and test 4. Bonferroni-adjusted comparisons revealed a .156 mean difference between the collaborative and the individual condition ($p = .001$, 95% *CI* of the difference = .069 to .244), indicating that during test 3, the collaborative condition ($M = .87$, $SD = .27$) had a higher output-bound accuracy for forgotten details compared to the individual condition ($M = .64$, $SD = 41$). This was also true for test 4, the collaborative condition ($M = .92$, $SD = .20$) compared to the individual condition ($M = .84$ $SD = .28$).

In sum, the output-bound accuracy for consistent details was similar, and very high, for both conditions (as in Experiment 1); details that were recalled had 97% or higher output-bound accuracy. Reminisced details had a greater output-bound accuracy for the collaborative condition

compared to the individual condition for test 3. Forgotten details had greater output-bound accuracy for the collaborative condition on tests 3 and 4 compared to the individual condition.

Examination of the Collaborative Recordings

To understand more about how collaborative pairs work together, we reviewed twenty-three recordings of the collaborative test. We first coded the degree of collaboration among the pairs and concluded that all pairs made a clear effort to participate and appeared to be engaged with the task. This determination was made by observing the interaction of the pair, making sure they both reported remembered details, and that a pair worked together instead of one person doing all of the work. The pairs were not instructed to use a specific strategy for recalling. However, 16 of the 23 of the partners took turns recalling details and the other seven pairs had one person recall everything they could and then had the other person do the same.

We examined who recalled more details in the pair. A binomial test with exact Clopper-Pearson 95% CI was done on the 23 pairs to determine if a greater proportion of the writers recalled more details compared to those assigned not to write (null hypothesis was equal recall from both participants). Of the 23 pairs, 6 (26.1%) writers recalled more details and 17 (73.9%) non-writers recalled more details. The writers reported significantly less details (95% CI of 10.2% to 48.4%, $p = .035$). An independent samples *t*-test found that the participant randomly assigned to be the writer recalled ($M = 17.86$) significantly fewer details than the other participant ($M = 24.83$), $t(44) = 2.44$, $p = .019$, $d = .72$.

Ten of the twenty-three pairs reported no intrusions in test 2. We reviewed how pairs handled intrusions by examining whether the pair had a verbal disagreement or discussion about an intrusion. Of the thirteen pairs that had intrusions, only four debated them. Three of the four

pairs that debated an intrusion corrected the intrusion (leaving it out of their final recall), the remaining pair debated it but included the intrusion in their final recall.

Discussion

Those who collaborated had a greater total recall on subsequent tests compared to those in the individual condition who recalled alone, and this was true for both tests (see Table 5). This replicates Harris, Barnier, & Sutton (2012); Rajaram & Pereira-Pasarin, (2010; collaborating leads to increased recall on subsequent tests.

Experiment 2 also revealed that collaboration led to more reminisced details than the individual condition on test 3. This contradicts the result of Experiment 1. This change could be due to the change of stimulus to a narrative, making it easier to reminisce different parts of the event (Alba & Hasher, 1983). The output-bound accuracy for reminisced details was also higher for the collaborative condition compared to the individual condition on test 3. We predicted that the collaborative condition would reminisce more minor details on test 3 and test 4, because details that drive the narrative after often recalled due to their importance of carrying out the event (Alba & Hasher, 1983) and it seems appropriate to infer that the collaborative condition would recall the key details that led the narrative during test 2 when the pair works together. Having this strong memory for the key details can potentially then help participants reminisce more minor details on subsequent tests. We did not find a test effect; however, overall, there were more minor details than key details reminisced in the collaborative condition.

General Discussion

The present research examined the impact collaboration has on the consistency in recall. Of primary interest was the examination of reminisced details. Experiment 1 showed that collaborating led to less reminiscing compared to those who recalled individually, with lower

output-bound accuracy compared to those who remembered alone. However, this cost of collaboration was only true for test 3. In Experiment 2, on the other hand, the collaborative condition reminisced more and had a higher output-bound accuracy compared to the individual condition. This benefit of collaboration was only found on test 3. Why did the material being learned impact how collaboration impacts reminiscing?

One possible explanation is that the stimuli used in Experiment 2 had a narrative structure. As a result, both members of the collaborative pair should have highly similar retrieval organizations of the narrative, in contrast to their unique retrieval organizations constructed for the forty random objects that made up Experiment 1. The more similar retrieval structure allowed the collaborators in Experiment 2 to work together more effectively than the collaborators in Experiment 1. According to the retrieval-strategy disruption hypothesis (Basden, Basden, Bryner, & Thomas, 1997), working with a partner to recall random objects can interfere with a person's organization of information, which can disrupt the process of retrieval. It is likely that each person in the pair had a different way of organizing the random objects. However, when considering the stimuli used in Experiment 2, recalling a narrative facilitates the creation of more similar retrieval strategies for the two collaborators. Thus, when the pair collaborates during test 2, they work to piece together the narrative. The collaborative condition then continues on to test 3, recalling individually and has the advantage of having been re-exposed to the key details, resulting in a stronger memory of the narrative in test 2. The increase in reminisced memories found during test 3 by the collaborative condition is likely due to them reminiscing details that they remember now that they have this more thorough understanding of what occurred. Considering the alone condition, they also benefit from the narrative, however, they are not re-exposed to the information, as in the collaborative condition, making it harder to

reminisce all of the details on your own. Taken together, when reminiscing objects, working with a partner on subsequent tests induces a cost of collaboration. However, when recalling a story narrative, collaboration provides a benefit by increasing the reminisce details on tests 3. Being that narratives are similar to events that happen in our day-to-day lives, these findings may be more informative regarding how collaboration impacts our ability to reminisce.

One finding that was clear in both experiments is that following collaboration, there is an increase in total recall (see also Harris, Barnier, & Sutton 2012; Rajaram & Pereira-Pasarin, 2010). This increase in recall is likely due to being reexposed to the studied information during collaboration (Blumen & Rajaram, 2008). In Experiment 1, this increase is seen during test 3 but not test 2. That is because on test 2 we find evidence of collaborative inhibition. An independent samples *t*-test revealed that the nominal condition (unique recalls from two randomly paired individuals) recalled ($M = 31.80$, $SD = 4.30$) significantly more than those in the collaborative condition ($M = 29.11$, $SD = 4.61$), $t(92) = 2.87$, $p = .005$. There was also a collaborative inhibition in Experiment 2; the nominal condition recalled ($M = 27.91$, $SD = 3.49$) significantly more than those in the collaborative condition ($M = 23.15$, $SD = 5.01$), $t(69) = 4.03$, $p = .000$). Collaborative inhibition is a well-documented phenomenon and a robust cost of collaborative remembering (Rajaram, 2011; Vredeveldt, Hildebrandt, & Van Koppen, 2016; Weldon & Bellinger, 1997).

The collaborative inhibition findings suggest that during collaborative recall there is a disruption to the retrieval strategy on test 2 that results in an individual recalling less than when remembering together (Basden et al., 1997). For example, one person may have the objects or event organized in a way that seemed logical to them, but their partner may disrupt this organization by starting to recall from a different starting point. Diehl and Stroebe (1987)

suggest that collaborative inhibition also may occur due to production blocking, which is a limitation due to having only person being able to speak at a time. Diehl and Strobe suggest a number of impacts of production blocking: One partner may forget his or her idea while the other is speaking, the value of what one person reports may make the other person feel that their ideas are not as valuable, or having to keep remembering what you want to report while your partner recalls things can interfere with your ability to remember new ideas. What is clear is that when individuals go from working together (test 2) to recalling alone (tests 3 and 4), we see a large increase in total recall. This increase can be explained by the individual now being able to organize the information that was re-exposed during test 2 in the way he or she prefers. Consequently, during test 3 and 4, they are able to reinstate a preferred strategy and recall what they remember without disruption.

When investigating how collaboration impacted forgotten details and intrusions. We found that more details were forgotten by the collaborative condition, especially on test 3. This decrease can be explained due to pairs working together on test 2, and then individually on test 3, and not being able to remember every detail their partner reported in test 2. Another benefit of collaboration is that you have a partner to discuss and confirm if what you believe is correct. The free-recall method allowed for pairs to prune out any details they disagreed on, although we observed only 3 of the 23 recorded collaborative pairs engaging in error pruning (Harris et al., 2013; Rajaram, 2011; Ross et al., 2008). The lower output-bound accuracy in the individual condition likely resulted from the participants in the individual condition carrying their errors forward to subsequent tests because they have no way to check if they are right.

Both experiments found that details that are consistently recalled are recalled with an extremely high output-bound accuracy, so good that potential effects of collaboration might have

been masked by a ceiling effect. The output-bound accuracy of consistent memories shows that the stability of output-bound accuracy does not change after multiple recalls, and this is true whether you recall alone or previously with a partner. Having high accuracy of consistent memories is a finding that has been found previously (Evans & Fisher, 2011; Smeets et al., 2017; Stanley & Benjamin, 2016). This stability in memory accuracy across tests was also found by Krix et al. (2015), which contradicted what police detectives believed would happen to accuracy over repeated testing.

One factor that can adversely influence the output-accuracy of consistent details is if participants are forced to recall a certain number of details. Koriat and Goldsmith (1996b) pointed out that when individuals are given the option to provide by free-report or free-recall, the person is given the opportunity to control what they report. When these are the circumstances, it is common for people to only report information they think is right (Koriat & Goldsmith, 1996b). High consistent output-bound accuracy goes hand and hand with being in control of your memory output and being able to report what you know is right while leaving out intrusions. However, what if there is a limit set to what you must remember. Consider a situation where a police officer encourages a witness to tell them more because they need more information. In these types of situations, the individual is pushed to report more than they feel comfortable doing, and this can adversely impact memory accuracy. If participants are not allowed to control what they report, they may feel encouraged to guess, which will result in the reporting of intrusions. Intrusions will also be more prevalent if stimuli are highly related. Take the Deese-Roediger-McDermott (DRM) paradigm, which found that if participants are presented with semantically related words (*e.g.*, emotion, fear, temper, rage) during encoding, it is highly likely that participants will recall words that were not originally studied but that have similar meanings

to the studied words (*e.g.*, anger). It can be expected that if DRM word lists were used, the amount of intrusions would increase, which would negatively impact the output-bound accuracy.

Limitations and Future Directions

Our study is not without its limitations. One limitation is that Experiment 1 was conducted in-person whereas Experiment 2 was conducted via Zoom due to the pandemic. In other words, stimulus type (objects vs. video) was confounded with method of conducting the experiment (in-person vs. Zoom). Although we believe that the differing stimulus type between Experiments 1 and 2 impacted our findings, it is possible that in-person versus Zoom also contributed. However, Ekeocha and Brennan (2008) had participants recalling a story as a group either face-to-face or in electronic groups and found that there were no significant differences in their recall proportions of correct and incorrect items. Perhaps Zoom facilitated the benefits of collaboration. For example, when pairs recall together on zoom, it may ease social anxiety compared to working together with a stranger in the laboratory.

The movie-clip used in Experiment 2 had a narrative that was about a summer camp, with a lot of details that could have been recalled. However, a future direction for this research could be to use a video involving a mock-crime event, because we know that eyewitnesses often experience a crime with others (Skagerberg & Wright, 2008) and previous eyewitness literature research has found that emotional stress can harm memory (Christianson, 1992). Being that many crimes are unpleasant events that often induce stress, it would wise to consider using a mock-crime event. This type of stimuli could look deeper into details that matter during crimes (e.g. clothing of the culprit, type of car, whether there were weapons).

In conclusion, the current literature has led to unsettled decisions as to whether co-witnesses communicating is harmful or helpful. Unfortunately, due to the differing results found

in our experiments, more research is needed to identify the impact that communicating has on co-witnesses. Both observed both costs and benefits of collaboration. We saw an initial cost of collaborating on test 2 where collaborative remembering results in reduced recall compared to nominal groups. This negatively impacts recall during the actual collaborative remembering task. But thereafter, whether you see a cost or benefit on reminiscing depends on what the stimulus was. Experiment 1, conducted in-person using memory for random objects, showed that collaborating negatively impacted the amount of reminisced details. Experiment 2, conducted on Zoom using a narrative video, showed that collaboration benefited the reminisced details recalled during test 3. Another advantage of collaborating is that it led to greater total recall on subsequent tests. Another benefit that derives from collaborative remembering is the ability to work through what is the correct and wrong information. This gives pairs an ability to discuss and evaluate their memories and prune out errors, which puts individuals recalling alone at a big disadvantage.

Recall changes over time and inconsistencies in memory does not indicate memory is unreliable (Stanley & Benjamin, 2016). It is normal for individuals forget and reminisce memories at different times. However, the accuracy of the reminisced details does tend to decline over multiple recalls whereas the accuracy of consistent details stays stable regardless of if you recall with a partner or not.

A practical implication of these experiments is that eyewitness statements should be taken individually rather than collaboratively. This is because we know that when collaborative remembering takes place, it leads to fewer recalled details. However, after collaboration, on subsequent recalls, it is likely that these individuals would have a better memory of the event because they were re-exposed to some details when recalling with other witnesses. Most crimes

occur when police are not present and witnesses will often communicate before the they arrive. However, as long as witnesses' statements are not collected together, there may be opportunity to retrieve a fuller report of what occurred.

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Table 1

Visual Representation of the Retention Possibilities

Study Phase

Test 1	Test 2	Test 3
		
		
		
		

Note. The top of the table depicts four studied objects: leaf, hanger, racecar, and button. Below are possible recalled objects on Tests 1, 2 and 3, which will serve to illustrate the following four classifications: Consistent, Reminisced, Forgotten, and Intrusions. The recall of the racecar is classified as consistent because it was reported on all three tests. The recall of the button on test 3

is a reminisce because this was its first recall. Despite being reported on test 1, the leaf also is reminisced in test 3 because it was not reported on test 2. Every time an object is forgotten and then later recalled, it is counted as reminisced. Forgotten objects were objects that were previously recalled, then not reported; the hanger was forgotten on test 3. Intrusions (key and lipstick) are objects that were falsely recalled by the participant.

Table 2

Experiment 1

Average frequency (SD) for recalled, consistent, reminisced, and forgotten items by condition and test

	Individual	Collaborative Condition
Test 3		
Consistent	19.56 (5.73)	18.93 (5.69)
Reminisced	2.39 (1.56)	1.68 (1.54)
Forgotten	1.15 (1.51)	3.91 (3.07)
Intrusions	.61 (1.02)	.50 (.77)
Total Recalled	**23.85 (5.17)**	**26.19 (5.93)**
Test 4	Individual	Collaborative Condition
Consistent	18.68 (5.56)	17.91 (5.81)
Reminisced	.93 (1.08)	1.35 (1.33)
Forgotten	2.46 (2.07)	5.44 (3.33)
Intrusions	.59 (.81)	.59 (.84)
Total Recalled	**24.32 (5.11)**	**26.72 (5.81)**

Note. Total recalled accounts for all the studied items recalled by a participant.

Table 3

Experiment 1

Output-bound accuracy (SD) for consistent, reminisced, and forgotten objects by condition and test

	Individual	Collaborative Condition
Test 3		
Consistent	.98 (.03)	.98 (.02)
Reminisced	.84 (.34)	.66 (.44)
Forgotten	.51 (.48)	.91 (.24)
Test 4	Individual	Collaborative Condition
Consistent	.98 (.03)	.99 (.03)
Reminisced	.50 (.49)	.63 (.47)
Forgotten	.82 (.35)	.99 (.01)

Table 4

Experiment 2

Average frequency (SD) for recalled, consistent, reminisced, and forgotten items by condition and test

	Individual	Collaborative Condition
Test 3		
Consistent	27.13 (9.30)	26.56 (9.74)
Reminisced	4.57 (4.59)	6.98 (4.30)
Forgotten	2.96 (4.07)	7.41 (5.58)
Intrusions	.62 (.80)	.53 (.91)
Total Recalled	37.38 (10.68)	42.08 (10.01)
Test 4	Individual	Collaborative Condition
Consistent	26.70 (9.51)	26.29 (9.66)
Reminisced	2.00 (2.24)	2.03 (2.09)
Forgotten	4.96 (5.55)	8.74 (6.45)
Intrusions	.36 (.57)	.35 (.73)
Total Recalled	38.32 (10.64)	43.32 (10.68)

Table 5

Experiment 2

Average frequency *(SD) for recalled, consistent, reminisced, and forgotten items by condition and test*

	Consistent	Reminisced	Forgotten	Intrusions	Total Recalled
Test 3					
Individual				.61 (80)	37.38 (10.68)
Key	10.94 (3.69)	.98 (1.67)	.72 (1.35)		
Minor	5.17 (2.66)	.94 (1.07)	.70 (.95)		
Extra	11.02 (4.61)	2.66 (2.51)	1.53 (2.52)		
Collaborative				.53 (.91)	42.08 (10.01)
Key	9.79 (4.05)	1.53 (1.38)	1.88 (1.79)		
Minor	4.20 (2.59)	1.85 (1.70)	1.95 (1.64)		
Extra	12.19 (5.28)	3.59 (2.80)	3.58 (3.66)		
Test 4					
Individual				.36 (57)	38.32 (10.64)
Key	10.74 (3.75)	.36 (1.21)	1.32 (1.69)		
Minor	5.04 (2.67)	.28 (.74)	1.02 (1.26)		
Extra	10.91 (4.68)	1.36 (1.22)	2.63 (3.76)		

Collaborative				.34 (.72)	43.32 (10.68)
Key	9.70 (4.07)	.46 (61)	2.19 (2.02)		
Minor	4.13 (2.59)	.49 (81)	2.20 (1.74)		
Extra	12.06 (5.28)	1.08 (1.37)	4.35 (4.22)		

Table 6

Experiment 2

Output-bound accuracy (SD) for consistent, reminisced, and forgotten objects by condition and test

	Individual	Collaborative Condition
Test 3		
Consistent	.97 (.04)	.98 (.06)
Reminisced	.77 (.33)	.93 (.12)
Forgotten	.64 (.41)	.87 (.27)
Test 4	Individual	Collaborative Condition
Consistent	.98 (.03)	.98 (.05)
Reminisced	.62 (.42)	.67 (.44)
Forgotten	.84 (.29)	.92 (.20)

Table 7.

Experiment 2 Key, Minor, and Example Extra Details

Key Details

S1.1. Rich people arrived in cars
S1.2. A cake was brought out for Moose
S1.3. Boy/Delany stood on a chair to get everyone's attention
S1.4. Boy/Delany fell off the chair
S1.5.The women scolded Delany after he fell and told him he was responsible for everything running smoothly.
S2.1 People were walking down to the docks/river/lake
S2.2.People get on the small paddle boats
S2.3. Scared and looking out for snakes
S2.4. Man tells Delany/Boy to take the lead boat
S2.5. Boy talks about Indian history
S2.6. Women panic and jump off the boat
S2.7. Delany/Boy stays and kills the snake
S2.8. Delany/Boy says the camp should have more contact sports(wrestling)
S3.1. Sullivan/Boy is being bullied
S3.2. Two boys push Sullivan/Boy into the water
S3.3. Delany/Boy comes to help and tells the two boys to scram
S3.4. Delany/Boy tells Sullivan/Boy that he is tired of sticking up for him
S3.5. Sullivan/Boy says he doesn't need his brother sticking up for him
S3.6. Sullivan/Boy doesn't have any friends because the others don't like him
S3.7. Sullivan/Boy runs away
S3.8. Older woman watches from the window

Minor Details

S1. 1. Everyone was chanting "Moose"
S1. 2. Details about the cake (Says Happy Birthday Moose, Brown-black cake, Blue letters)
S1. 3. The women says that there are over 500 causes to donate to the camp
S1. 4. The cook gives Boy/Delany a chair
S1. 5. Boy/Delany falls onto food
S2.1. People are going on a tour of the lake
S2.2. Boy gets into the boat with the snake
S2.3. A boy jumps into the water
S2.4. Everyone tells Delany/Boy to jump out of the boat
S2.5. Man takes the paddle with the snake and waves it congratulatory in the air
S2.6. The older lady looks annoyed
S3.1. One boy jumps into the water to push Sullivan/Boy/him under water
S3.2. Delany/Boy/Older brother helps Sullivan/Boy/Younger brother out of the water
S3.3. The other two boys run away laughing
S3.4. Sullivan/Boy/Younger brother is upset because no one wants to be his friend
S3.5. Delany/Older boy suggests moving him to another cabin
S3.6. Delany/Older boy tells Sullivan/Younger boy to get some friends to stick up for him

Extra examples

1. A miscommunication between the women as they discuss whether or not there will be snakes on the boat
2. Delany was trying to inform every one of their plans for the afternoon
3.Sullivan runs off the dock crying

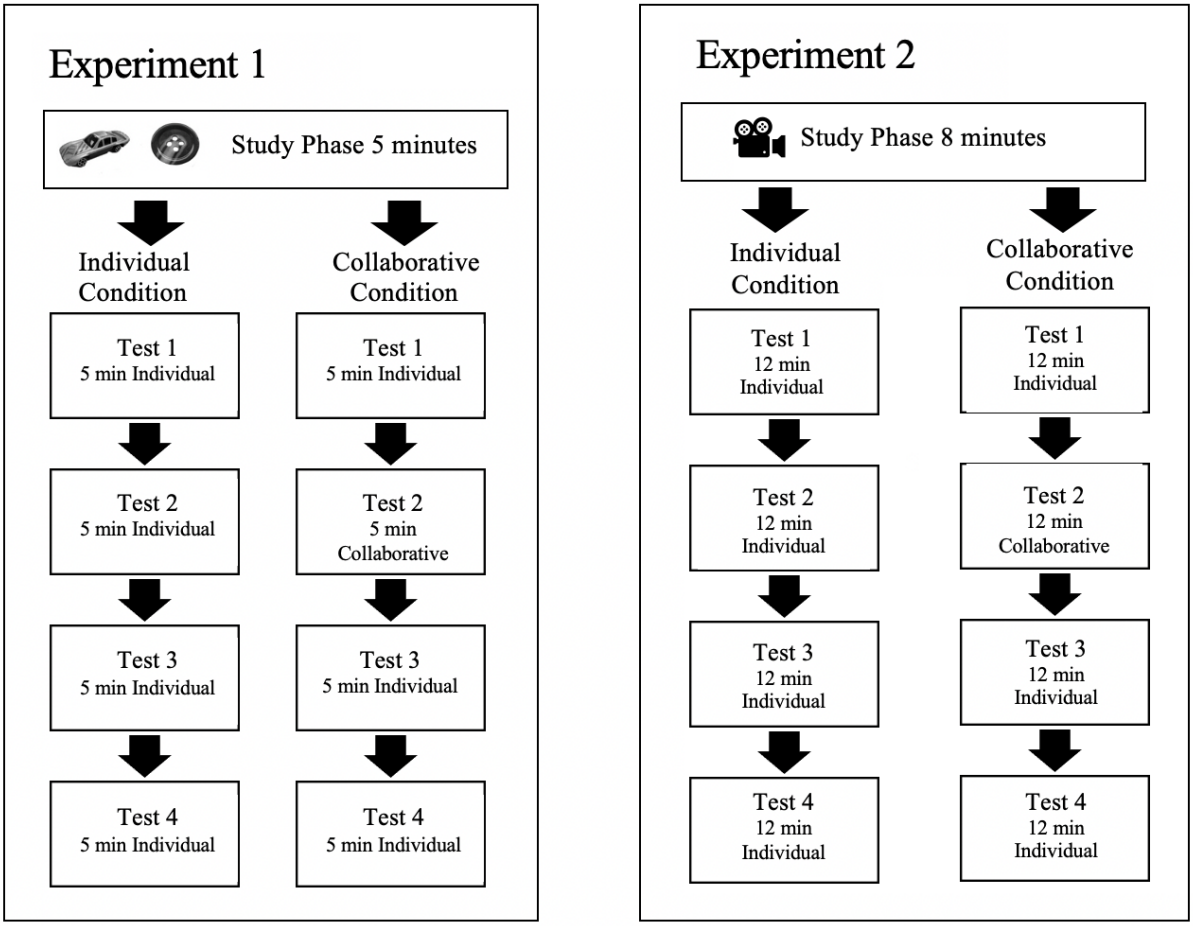

Figure 1. The left-hand panel gives the Study Design for Experiment 1 and the righthand panel gives the Study Design for Experiment 2. The downward arrows indicate a 3-minute filler task.

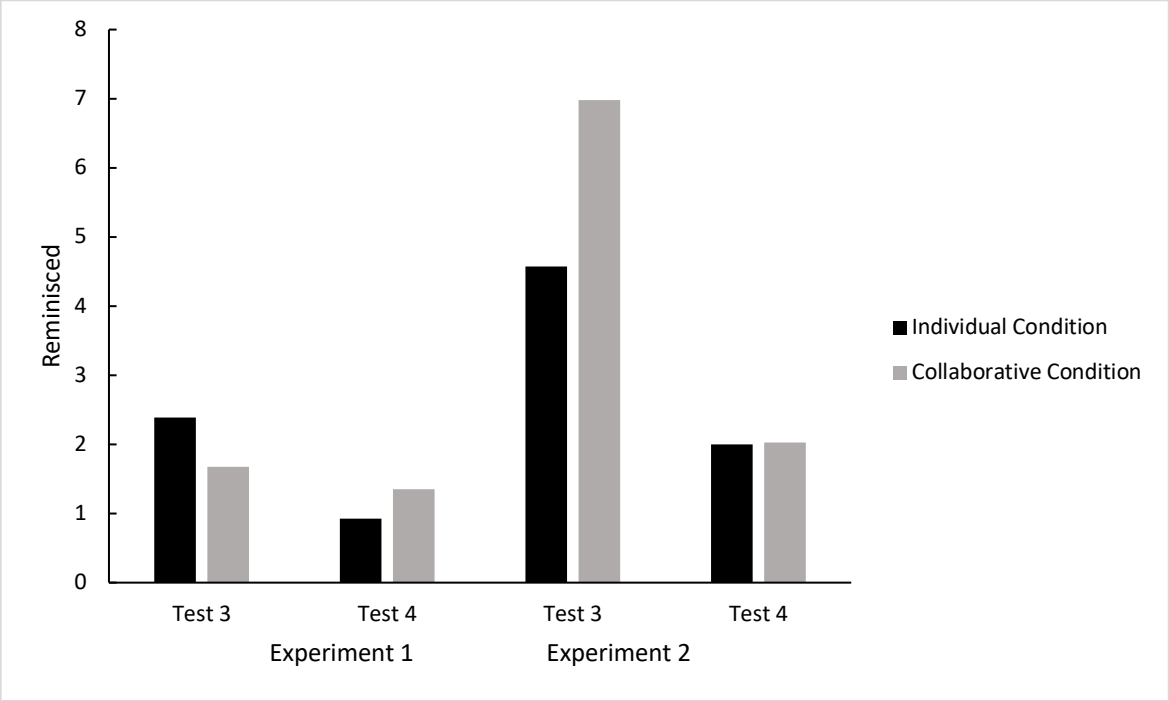

Figure 2. Reminisced objects from test 3 and test 4 in Experiments 1 and 2. The individual condition refers to IIII and the collaborative condition refers to ICII.

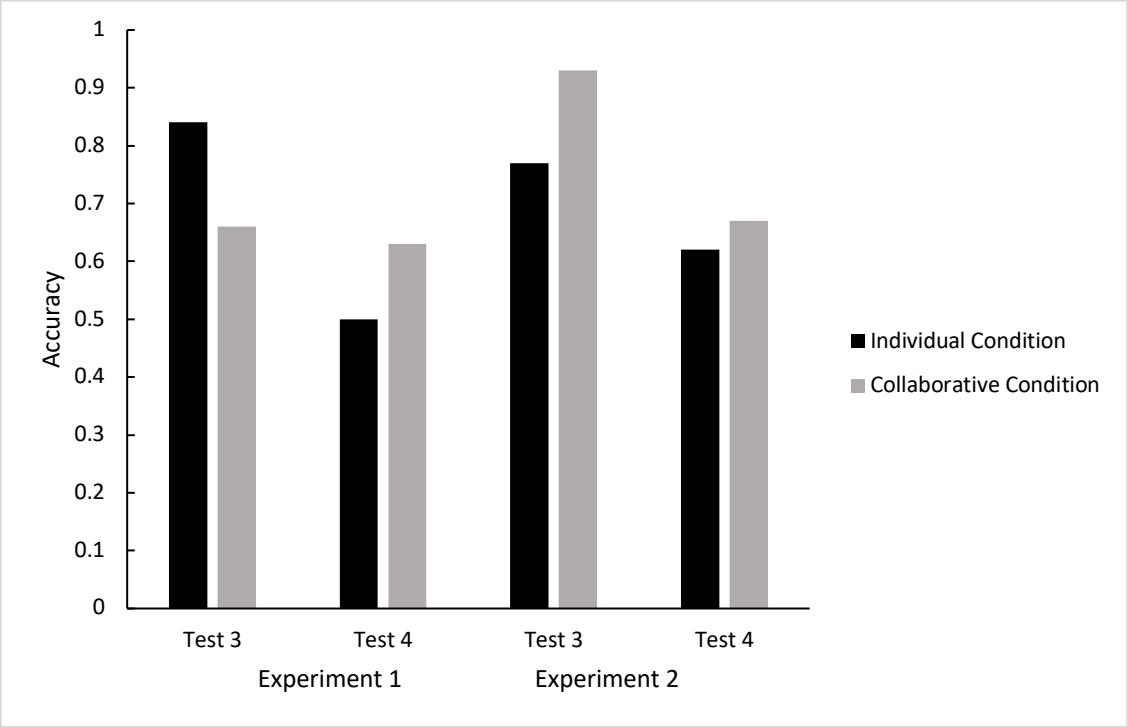

Figure 3. The output-bound accuracy of reminisced objects for test 3 and test 4 in Experiments 1 and 2.

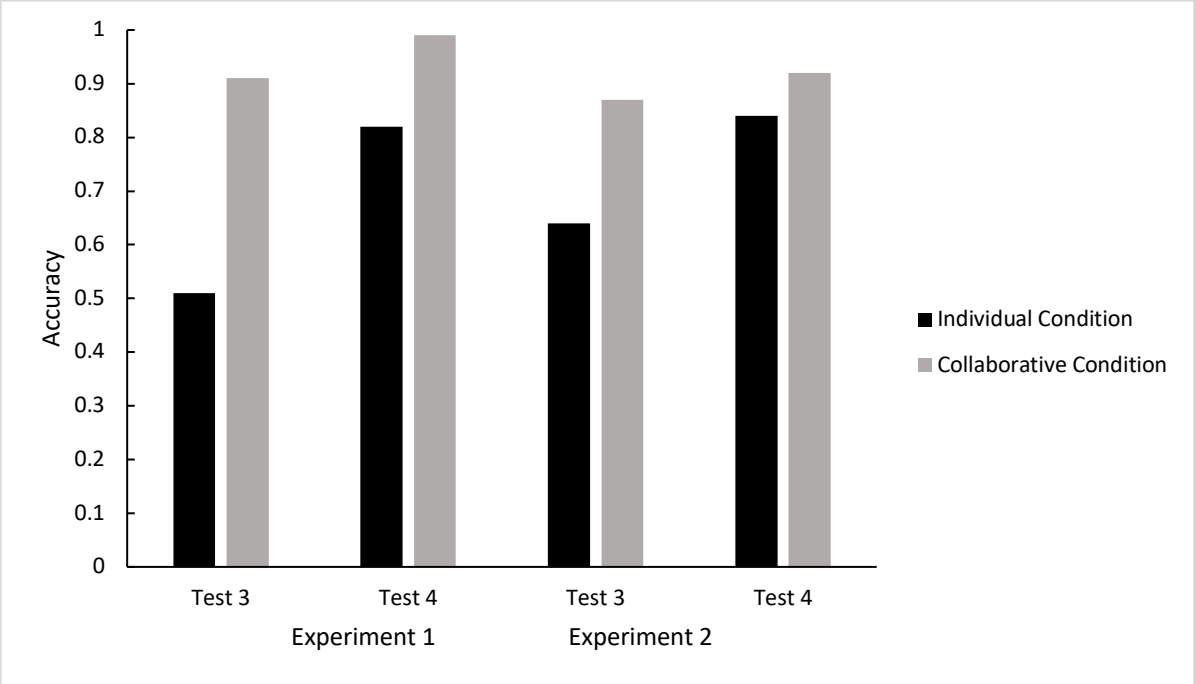

Figure 4. The output-bound accuracy of forgotten objects for test 3 and test 4 in Experiments 1 and 2.

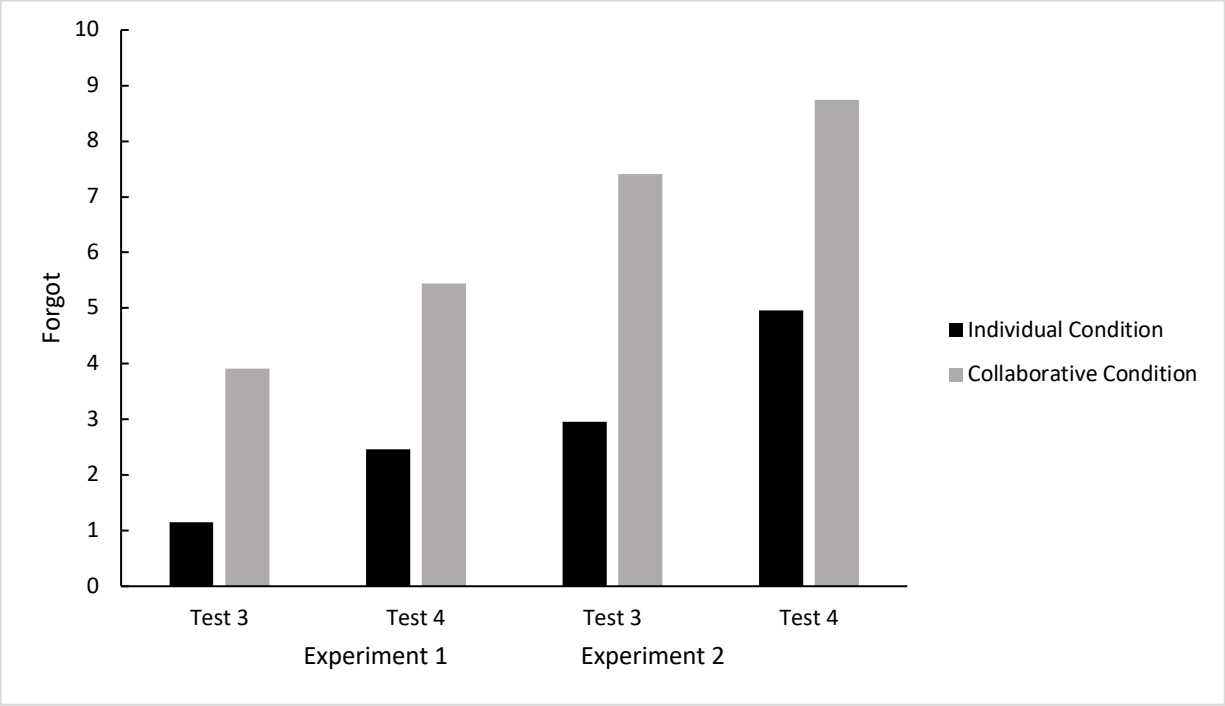

Figure 5. Forgotten details from test 3 and test 4 in Experiment 1 and 2. The individual condition refers to IIII and the collaborative condition refers to ICII.

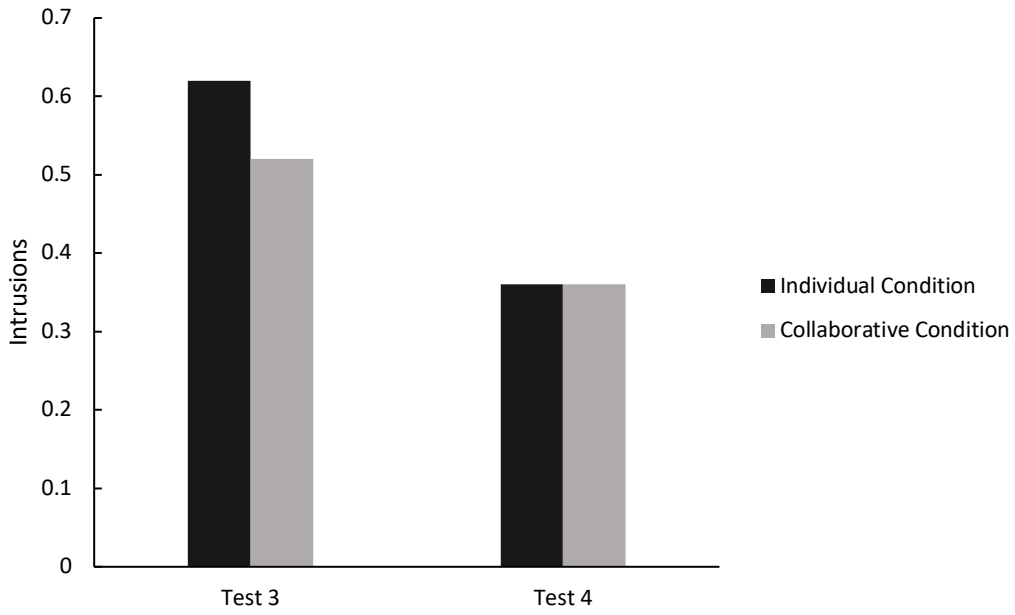

Figure 6. Intrusions from test 3 and test 4 in Experiment 2. The individual condition refers to IIII and the collaborative condition refers to ICII.