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Abstract

Two experiments investigated the recall of nominal and collaborating groups to test the hypotheses that (a) semantic memory, as well as episodic memory, is disrupted by collaborative recall and (b) both episodic and semantic recall will be greater in groups collaborating via computer mediated communication (CMC) than groups collaborating face-to-face. Experiment 1 investigated different collaborative constellations (nominal, face-to-face and parallel CMC) in a series of episodic and semantic word recall tasks. In Experiment 2, collaborative groups (nominal, face-to-face, parallel CMC and cyclic CMC) completed a Scrabble task in which they were required to generate words from a set of 12 letters. Both experiments demonstrated that collaborative inhibition was present in semantic recall. Parallel CMC improved recall by comparison to face-to-face collaboration in both experiments, whereas cyclic CMC did not. The underlying causes of collaborative inhibitory effects and the potential for reducing them with CMC are discussed.

Keywords: collaborative inhibition, computer mediated communication, semantic recall, episodic recall

Collaborative Inhibition and Semantic Recall: Improving Collaboration through

Computer Mediated Communication

Despite the intuitive appeal of collaboration, research has consistently

demonstrated that collaborative groups do not recall as much episodic information or

generate as many ideas as "nominal" groups, that is the combined efforts of

individuals working independently (Andersson & Ronnberg, 1995; Basden, Basden &

Henry, 2000; Diehl & Stroebe, 1987, 1991; Weldon & Bellinger, 1997; Weldon, Blair

& Huesbsch, 2000). This deficit in collaborative performance is supposed to arise

from a variety of effects experienced by collaborating group members working in the

presence of others. These effects evidently counteract any benefits of collaboration,

such as the inspiration or development of ideas, cueing of memories and so forth

(Diehl & Stroebe, 1987; Hymes & Olson, 1992; Jablin & Seibold, 1978; Meudell,

Hitch & Boyle, 1995; Weldon & Bellinger, 1997).   In our research we draw upon

findings from memory and brainstorming research to answer two rather novel

questions for collaborative recall, namely: 1) is semantic recall susceptible to

collaborative inhibition and 2) can computer mediated communication (CMC)

improve collaborative recall?

Collaborative Inhibition and Productivity Loss

The finding that collaboration reduces a group's output is widespread

throughout brainstorming and recall research. However, explanations for the causes

of this effect differ between each field. In brainstorming, the deficit is known as

productivity loss, whereas in collaborative recall it is referred to as collaborative

inhibition. Whilst memory research has largely ruled out productivity loss

explanations, we suggest that brainstorming research can nonetheless highlight new

ways of examining collaborative recall. In order to do this, we outline the differences

between the two before moving on to describe our experimental hypotheses.

In brainstorming, three factors are generally supposed to contribute towards productivity loss: 1) Production blocking – typically only one group member can contribute at once, hence group members must defer their contribution until their turn. Thus they may forget or abandon their contributions (Diehl & Stroebe, 1987; Lamm and Tromsdorff, 1973). 2) Evaluation apprehension – group members may withhold answers for fear of negative evaluation by other group members (e.g. Collaros & Anderson, 1969; Diehl & Stroebe, 1987).   3) Social loafing – group members may exert less effort because they alone are not responsible for the output, or they may feel their effort is dispensable and will not make a difference (Kerr & Bruun, 1983).

Alternatively, in collaborative recall, the dominant explanation for collaborative inhibition is retrieval strategy disruption; the notion that every individual has an idiosyncratic retrieval strategy, which is disrupted through exposure to others' recall output (Basden et al., 1997; Blumen & Rajaram, 2008; Finlay, Hitch & Meudell, 2000; Wright & Klumpp, 2004). The robust findings of retrieval strategy disruption have led many investigations to discount productivity losses as accounts for the collaborative deficit. Weldon et al. (2000) ruled out social loafing when experimental manipulations designed to increase motivation to recall did not eliminate collaborative inhibition. Similarly, Finlay et al. (2000) found that using cues to prompt recall eliminated collaborative inhibition, which was also reduced by manipulating the order in which participants recalled. Neither of these findings could be attributed to relief from social loafing or production blocking.

To date, the evidence for retrieval strategy disruption primarily lies in episodic recall. Episodic memory comprises information that is particular to the time and place of encoding (Andersson & Ronnberg, 1996). It is less organised and considered to be more vulnerable than semantic memory (Tulving, 1983), which comprises overlearned material and general knowledge stored in long-term memory. For these

reasons, semantic memory is sometimes assumed to be immune from collaborative inhibition (Andersson & Ronnberg, 1996; Weldon, 2000) and has so far received little attention in collaborative inhibition research. However, semantic recall can still fail, people regularly forget well-known information, for example names, birthdays and so forth. Moreover, recent research has shown retrieval inhibition to be an underlying factor of collaborative inhibition (Barber, Harris & Rajaram, 2015). We therefore posit that semantic recall may be susceptible to interference from other people. Our hypothesis is drawn from brainstorming research and inhibitory effects in individual semantic recall, outlined below.

Brainstorming and recall are clearly different tasks, however the process of generating ideas begins with a repeated search for ideas and cues in long-term memory (Nijstad & Stroebe, 2006). Indeed, some semantic recall tasks may resemble brainstorming tasks and vice versa, and in some studies, classifications of brainstorming and semantic tasks have been interchangeable. For instance, Vallee-Tourangeau et al.'s (1988) semantic recall task was 'uses of a mirror', and Bouchard's (1972) brainstorming task was 'uses of an old tyre'. Instructing individuals to brainstorm or recall is likely to influence how they approach tasks. However, at the group level, it seems unlikely that instructing to recall rather than brainstorm would protect output from interference.

Moreover, interference in semantic recall has already been demonstrated in individual recall. Johnson and Anderson (2004) found that when individuals recalled words from general knowledge, the meaning of an ambiguous word suppressed concepts related to its alternate meaning, lowering overall recall. For example, presentation of the word *sock* alongside the verbs *punch* and *injure* inhibited the recall of the associated word *footwear*. Johnson and Anderson (2004) claimed this process is analogous to the inhibitory mechanism that produces forgetting in episodic recall.

In collaborative recall, a limited number of studies have explored the notion of inhibition in semantic recall and have produced mixed findings across a variety of tasks. Collaborative inhibition was present when groups recalled US states, reconstructed maps and recalled figures (Weldon, 2000). Alternatively, collaborative facilitation was evident when groups answered general knowledge questions (Weldon, 2000), history questions (Andersson & Ronnberg, 1996) and listed the names of people in their Protary/Robus club (Harris et al., 2011). Weldon (2000) explained this discrepancy with the concept of cueing. Cues (e.g. questions to answer) provide group members with target-specific material that facilitates retrieval, whereas uncued tasks allow for idiosyncratic organisation, and group members might disrupt each other as they recall in different orders.[1] Further, it must be noted that Weldon's (2000) findings were only preliminary and the data were taken from distractor tasks that were used in other experiments.

In Experiment 1, we used an orthographically cued semantic recall task, in which participants were required to generate words beginning with a specified digraph (e.g. BR). Our reasons for choosing this style of task were: no specialised knowledge is required, meaning that any English speaker can take part and idiosyncratic retrieval strategies – the order in which items are retrieved from memory is personal to each individual. Thus, we hypothesise:

- In semantic recall, collaborative inhibition will cause collaborative groups to recall less than nominal groups (Nominal > Collaborative)

So far, the brainstorming literature has helped us to reason that collaborative inhibition may extend to semantic recall. In addition to this, brainstorming studies have found that computer mediated communication can improve collaborative output.

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[1] Whilst Harris et al.'s (2011) task was also uncued, their focus was on elderly couples with shared memories, hence it is not surprising that inhibitory effects were absent.

In the next section we turn our attention to explore whether these findings might also extend to episodic and semantic recall.

CMC

In collaboration, both recall and brainstorming involve first recalling information/thinking of an idea and then evaluating whether that contribution is correct and suitable for inclusion in the group output. The medium by which people interact can therefore influence how they go about communicating information. In face-to-face communication, speaking is quick and group members can easily communicate uncertainty or provide feedback to each other via non-verbal cues. Alternatively, discussion via CMC is slower; typing and waiting for a response means that non-verbal cues are lost, but the output can be reviewed, in contrast to speech, which is ephemeral.   People may also feel more confident in saying things via CMC (Sproull & Kiesler, 1991) or they may be more inclined to loaf as they feel less direct responsibility to communicate (Ekeocha & Brennan, 2008).

Brainstorming research has investigated whether CMC can improve collaboration by directly tackling productivity loss in face-to-face groups (e.g. Dennis, Valacich & Nunamaker, 1990; Dennis & Valachich, 1994; Gallupe, Bastianutti, & Cooper, 1991; Pinsonneault, Barki, Gallupe & Hoppen, 1999; Pissarra & Jesuino, 2005). The provision for all group members to contribute items simultaneously can remove production blocking (Gallupe et al., 1991; Jessup, Connolly & Galegher, 1990) and anonymity can eliminate evaluation apprehension (Dennis & Valacich, 1994). It seems logical that the benefits offered by CMC could also apply to collaborative inhibition in recall, although surprisingly little work has examined this. Ekeocha and Brennan (2008) found that face-to-face and CMC group episodic recall were equivalent, but that CMC caused group members to approach the recall task differently than face-to-face groups. Face-to-face groups relied more on

each other to evaluate and filter out items for inclusion in the final group product, whereas CMC group members tended to self-filter their contributions. This occurred, Ekeocka and Brennan (2008) argue, because typing and waiting for a response via CMC took more time and effort than speaking.

Extending Ekeocha and Brennan's (2008) findings, we predict that CMC may offer further benefits to collaborative recall that can reduce retrieval strategy disruption. In Experiments 1 and 2 we explore "parallel" CMC, which allows all group members to communicate synchronously; they can type their contributions simultaneously and the output is distributed to other group members' screens. Theoretically this configuration could allow group members to work as a nominal group initially and upon exhaustion of recall, turn to the group output to potentially stimulate the production of additional items. Alternatively, this may enable group members to ignore each others' contributions or attend to them at their convenience, promoting the opportunity to use personal retrieval strategies. We predict:

- CMC will reduce collaborative inhibition in episodic and semantic recall (Nominal > Parallel CMC > Face-to-face).

In addition to the potential benefits of collaboration CMC may introduce, CMC allows us to gather additional process data from each group member. This allows a closer exploration of the processes of collaborative recall and the nature of retrieval strategy disruption. A rationale for these analyses is as follows:

Instance repetitions. We posit that group members using CMC have more opportunity to use personal retrieval strategies because they are freed from the disruption of turn-taking and hearing others' responses. In principle, CMC allows group members to ignore each other's output or at least to partially attend to them. If they were to do this perfectly, they would be recalling under very similar conditions to nominal group members. We suggest that instance repetitions across a group's

recall protocol offers a useful index of this partial attention – completely ignoring others' outputs would presumably result in as many repetitions as are apparent in nominal group responses. Therefore, this may also provide insight for retrieval strategy disruption in collaboration. For episodic and semantic recall we predict:

- CMC groups will generate more instance repetitions than face-to-face groups, but fewer instance repetitions than nominal groups (Nominal > Parallel CMC > Face-to-face)

Clustering analyses. Many researchers have explored retrieval strategy disruption by analysing how individuals and groups organise episodic recall (Barber & Rajaram, 2011; Basden et al., 1997; Basden et al., 2000; Finlay et al., 2000; Hyman, Cardwell & Roy, 2013). If an individual's organisation of recall represents their preferred retrieval strategy, then a deviation from this organisation might indicate retrieval strategy disruption. Thus, collaborative inhibition has been evident when groups have had more (Finlay et al., 2000) and less organised (Basden et al., 1997) recall than individuals. It seems that the nature of collaboration influences a group's organisation, for instance, group members could collaborate freely in Finlay et al.'s (2000) studies, whereas Basden et al. (1997) used forced turn taking where group members could contribute one item at a time.

In the episodic task we used categorised words, which enable us to analyse organisation in terms of the extent to which group members recall in category clusters. In the semantic task we asked participants to generate words beginning with particular digraphs, e.g. *BR*. Thus, similarly, we were able to analyse the extent to which group members clustered recall, but now in terms of spelling, that is, letters following the digraph prompt.

Group members were able to contribute freely, and each might feel that a contribution in the same category as another's preceding contribution is a friendlier

gesture than would be a change of category. Therefore we predict that face-to-face group members will co-ordinate their recall, producing higher clustering than individuals. In the case of parallel CMC a prediction is harder to make. We suspect members of these groups are better able to ignore other members' contributions, and there is no need at all to manage turn-taking. Indeed because simultaneous contributions are allowed in CMC groups, members may pursue independent clusters, ignoring each other's contributions and thus will tend to produce lower clustering than both face-to-face groups and individuals. Hence:

- (Face-to-face > Individual > Parallel CMC)

Further, the parallel CMC condition allows us to gather data from each group member, enabling us to compare clustering for parallel CMC individual group members with nominal individuals. Because we expect that parallel CMC group members will influence each others' recall to some degree (that is, they will not ignore each other completely), we predict that clustering will be lower for parallel CMC individuals:

- (Individual > Parallel individual)

Experiment 1

Method

Participants and Design. Fifty-four native English speakers from the University of Manchester volunteered to take part in the study. The mean age was 21.7 years (21 males, 33 females). Participants were recruited through an advertisement placed on the university website. The incentive for participation was a £5 high street shopping voucher. Participants collaborated in triads, which were composed according to arrival at the lab with no regard to gender. They completed 3

episodic and 3 semantic tasks and the ordering of the conditions was counterbalanced using a randomised Latin Squares design, which was generated using the EDGAR (Experimental Design Generator and Randomiser) program (Brown, 2005).   Even though the episodic and semantic conditions were intermingled, the data for the episodic and semantic conditions were analysed separately, hence the experiment combined two sub-experiments, both using within-subjects designs to test for differences between three collaboration conditions: Nominal vs. Face-to-Face vs. Parallel CMC. The allocation of tasks to conditions was fully counterbalanced.

Each condition was set up as follows:

- Nominal – Each participant was allocated to a private computer in a different corner of the room, so that all group members sat with their backs facing one another. There was a distance of approximately 5 m between each participant. They were informed at recall that they would be working alone for the duration of the trial. They were not informed that their recalled items would later be pooled to form a nominal group contribution.

- Face-to-face – One participant was asked to serve as the typist. They remained the typist for both episodic and semantic face-to-face recall trials. Participants were seated round one computer and the typist sat in the middle.

- Parallel – The same seating configuration as nominal groups was applied. Participants were informed that they would all be present in the same session, meaning that their contributions would be visible to all group members and identifiable to the group by their designated experimental ID.

For the episodic tasks, encoding was conducted in accordance with the configuration of the condition, that is, episodic trial-words were displayed to individuals whilst they were physically separated in the nominal and parallel

conditions, and participants viewed them together round one computer in the face-to-face condition (as in the studies by Basden et al., 1997). This set up confounds encoding conditions with recall conditions, but ensures that in all cases there is no change of context between encoding and recall. Given the well established finding (since Godden & Baddeley, 1975) that a shift of context between encoding and recall will disrupt performance, this seems to us a better design than one in which encoding conditions are fixed and recall conditions are different to these only for some groups, thus confounding context-change with condition. In any case, given that the only difference for face-to-face encoding is that the computer is shared between participants who are seated in a row of three and not interacting, we anticipate that this will not be a factor affecting later recall.

Further, there is a limitation to this approach in that knowing whether subsequent recall is individual or collaborative may influence a participant's approach to encoding. To mitigate this, participants were not informed which recall condition would follow encoding. For nominal and parallel CMC groups we provided no indication of whether subsequent recall was individual or collaborative. However, it seems likely that participants would anticipate face-to-face recall following face-to-face encoding and may have made guesses about the other conditions by the end of the study.

Materials and Apparatus.

Software. The participants used Windows Live Messenger version 8.5.1302 (http://download.live.com/messenger) to record their answers. Windows Live Messenger is a type of chat software that permits one-to-one and group chat. Contributions are not anonymous as each user has an ID and users type their contributions and publish them to the conversation thread upon pressing *Enter*. A

number of Windows Live Messenger accounts were opened for the study. An account
was also created for the experimenter in order to monitor and initiate all conversations
and so that participants had a recipient to send messages to. The size of conversation
windows was maximised throughout the experiment so that participants could see the
maximum number of previous contributions possible throughout the recall trial.
Windows Live Messenger scrolled down automatically when the window became
full. The screen became full when 29 items were listed. Participants in the same
conversation in the parallel condition were able to scroll up and down without
affecting the views of the other participants' conversation windows.

     Episodic task. Three study lists were compiled from Battig and Montague's
(1969) updated category norms (Van Overschelde, Rawson, & Dunlosky, 2004), each
comprising 9 instances from 10 taxonomic categories.   All lists were of low
taxonomic frequency ($M = 0.1$). In each episodic condition, one of the lists was
randomly sorted and presented to the participants via a PowerPoint slideshow. The
three lists were counterbalanced across the three conditions. Each word was displayed
in bold black 44pt Arial font and was presented centred on a white background. The
presentation displayed each word in turn at a 2-second rate.

     Semantic task. Three orthographic digraphs were used; *BR, HE* and *PO*. The
reasons for using these semantic retrieval stimuli were twofold; firstly, orthographic
categories are unavoidably used on a daily basis in language processing and while
some people will have larger vocabularies than others, everyone should have a
relatively large number of items stored. The three digraphs were counterbalanced
across the three experimental conditions. Second, whilst not directly analogous to
brainstorming, the generative aspect of the task offers the opportunity for words to
stimulate the retrieval of similar or related words, for instance *pot* may provoke the

items *pots, potted, potential* and so forth. Alternatively, a disadvantage could be that participants place too much focus on generating similar words.

      Procedure. At the start of the experiment, participants were shown how to use Messenger. Participants then undertook the recall tasks in the order designated to them. For the episodic recall tasks, the following instructions were issued prior to presentation; "You will be shown a slide show of 90 words, please attempt to memorise as many as possible. The word list comprises 10 categories, each category contains 9 words. When you attempt to recall the words, you will be provided with a list of the category names, however from the slide show alone, the categories will not be obvious, for example the word *line* as part of the category *dance.*"

      The words within each list were presented in the same randomised order in all episodic tasks. Following encoding of the episodic items, participants were presented with a distractor task, which involved completing Suduko puzzles for 1 minute. The puzzles were always completed individually. Then, in the recall trial, participants were presented with a sheet of paper listing the word categories (1 x piece of paper shared between group members in the face-to-face condition and 1 x piece of paper for each individual in the nominal and parallel conditions). The sheet of paper was visible throughout the recall trial. The instructions issued for recall in the episodic task were: "Work individually/together to recall as many words as you can, using the provided categories to help you. You have 8 minutes to recall as many items as you can. Please attempt to recall for the whole of this duration. The experimenter will start the recall trial by sending a message, when this happens, reply to the message listing your recalled items by typing one item at a time and pressing 'Enter'". The process of pressing *Enter* after each recalled item ensured it was made visible to the group as soon as it was generated and also allowed recalled items to be time stamped.

For the semantic recall tasks, a different orthographic category was used for each of the 3 conditions, that is, participants only recalled from one category in a given condition. The instructions were the same as those issued in the episodic task and the first sentence was adapted for the context of the semantic recall task as follows: "Work individually/together to recall as many English words as you can, beginning with *PO/BR/HE…*" The digraphs were counterbalanced across experimental conditions.

For both episodic and semantic recall, participants in the face-to-face and parallel CMC conditions received no instruction as to whether they had to agree on answers before adding them to the list. Further, no instructions were provided on how to resolve disagreements. In the face-to-face condition, items that were filtered out verbally and not reported via Messenger were not counted in the final score.

Upon commencing the recall trials, the experimenter monitored the conversations for the full duration but made no contribution. The experimenter instructed the participants to stop recalling when the 8 minutes had elapsed. At the end of the experiment, participants were debriefed and thanked for their participation.

Results and Discussion

Scoring

In the episodic task, words were scored as correct only when they exactly matched those that had been presented (one point per correct answer). In the semantic task, all words that started with the presented digraph and were entries in *Merriam Webster's Collegiate Dictionary* (2005) were scored as correct. Spelling mistakes as judged by the experimenter (first author) were permitted in both sets of tasks. Timings scores measured general output and so included all data.   Instance repetitions and incorrect items were excluded from analyses of correct items and were analysed separately.

For analyses of main effects, alpha levels of .05 were used. In addition to these analyses, we wanted to make comparisons between pairs of conditions, e.g. face-to-face vs. parallel CMC. Because these comparisons were planned a priori, planned comparisons were conducted using a Bonferroni adjusted alpha of .025 per test. For instances where planned comparisons were orthogonal, the standard alpha of .05 was applied.

Table 1 displays the mean scores for correct items, instance repetitions, clustering and incorrect items.

Correct items

Episodic and semantic tasks were analysed separately. Overall, the results provided mixed support for the hypotheses. First, nominal group recall was greater than collaborative recall in both episodic and semantic recall. A one-way repeated measures ANOVA for episodic recall (Nominal vs. Face-to-face vs. Parallel) demonstrated a significant main effect, $F(2,34) = 9.963$, $p < .001$, $\dot{\eta}^2 = .587$. Planned comparisons revealed that nominal groups recalled more than face-to-face groups, $F(1,17) = 24.116$, $p < .001$, $d = 1.06$ and parallel CMC groups, $F(1,17) = 8.369$, $p = .010$, $d = .76$. We predicted that parallel CMC groups would recall more items than face-to-face groups, however a planned comparison was non-significant, $F(1,17) = 0.925$, $p = .350$, $d = 0.2$.

For semantic recall, our hypotheses were more fully supported: output varied across all conditions. A one-way repeated measures ANOVA (Nominal vs. Face-to-face vs. Parallel) demonstrated a significant main effect, $F(2,34), = 10.716$, $p < .001$, $\dot{\eta}^2 = .387$, where nominal groups recalled more items than face-to-face and parallel CMC groups. Planned comparisons demonstrated more items recalled for nominal than face-to-face groups, $F(1,17) = 20.072$, $p < .001$, $d = 1.07$, and for nominal than

parallel CMC groups, $F(1,17) = 7.255$, p $= .015$, $d = .55$. Further, parallel CMC groups recalled more than face-to-face groups, $F(1,17) = 4.933$, p $= .040$, $d = .63$. These results therefore provide preliminary evidence that semantic recall is susceptible to collaborative inhibition.

Instance repetitions

Overall, the results provided support for our hypotheses. A one-way repeated measures ANOVA for episodic recall (Nominal vs. Face-to-face vs. Parallel) revealed a significant main effect, $F(2,34) = 126.698$, p $< .001$, $\dot{\eta}^2 = .882$. Planned comparisons demonstrated that nominal groups generated more instance repetitions than face-to-face groups, $F(1,17) = 179.212$, p $< .001$, $d = 3.18$, and parallel CMC groups, $F(1,17) = 166.975$, p $< .001$, $d = 2.81$. However, contrary to our hypothesis, a planned comparison for parallel vs. face-to-face recall was non-significant, $F(1,17) = 1.118$, p $= .305$, $d = -0.30$.

For semantic recall, a one-way repeated measures ANOVA (Nominal vs. Face-to-face vs. Parallel) revealed a significant main effect, $F(2,34) = 52.438$, p $< .001$, $\dot{\eta}^2 = .737$. Planned comparisons demonstrated that nominal groups generated more instance repetitions than face-to-face groups, $F(1,17) = 81.321$, p $< .001$, $d = 2.88$, and parallel CMC groups, $F(1,17) = 46.776$, p $< .001$, $d = 1.48$. Additionally, parallel CMC groups generated more instance repetitions than face-to-face groups, $F(1,17) = 15.519$, p $= .001$, $d = 1.3$. These results provide stronger evidence that group members partially attended to each others' contributions in parallel CMC collaboration. Further, the equivalent levels of attention to each others' contributions, aligns with the equivalent correct recall for face-to-face and parallel CMC groups.

Clustering

Table 1 displays the mean clustering scores for episodic and semantic recall. The adjusted ratio of clustering (ARC) measure, developed by Roenker, Thompson and Brown (1971) was used to assess levels of clustering. The ARC measure calculates an index, where clustering can be at maximum (the value of the index = 1.00) or clustering can be at chance level (the value of the index = 0). If clustering was at maximum, then participants would have recalled all items category by category and if clustering was at chance level then no two items from the same category would have been recalled in succession. In line with Basden et al.'s (1997) analyses, the occurrence of incorrect items and instance repetitions of items within a sequence was ignored. As the ARC measure was inapplicable to nominal group scores, clustering measures were taken for individual participants. Clustering scores for face-to-face and parallel groups were calculated in the same way as an individual participant's protocol. Further, clustering scores were also calculated for individuals within the parallel CMC condition and analysed separately.

A mixed ANOVA (group, individual) for episodic recall, demonstrated significant main effects, $F(1,17) = 15.151$, p = .001, $\dot{\eta}^2 = .471$ (within subjects) and $F(1,17) = 87.655$, p < .001, $\dot{\eta}^2 = .838$ (between subjects). We predicted that face-to-face groups would exhibit more clustering than individuals and parallel CMC groups. An independent t-test for face-to-face vs. individual was non-significant, $t(69) = .910$, p = .366, $d = 0.25$, however face-to-face groups clustered more words than parallel CMC groups, $t(17) = 3.893$, p = .001, $d = 0.63$, and individuals clustered more items than parallel CMC groups, $t(39.449) = -2.849$, p = .007, $d = 0.72$. In this comparison, Levene's test indicated unequal variances, $(F = 5.998$, p = .017) so degrees of freedom were adjusted from 69 to 39.449. The analysis for nominal individuals vs. parallel CMC individuals was non-significant., $t(53) = -.281$, p = .780, $d = -0.04$.

One explanation for this may be our use of words that were low in taxonomic frequency; because the words were not obviously associated to categories, participants may have been less reliant on using them to organise recall. Basden et al. (1997) used words that were high in taxonomic frequency and found higher clustering for individuals than face-to-face groups. However, they used a strict turn-taking procedure in contrast to our free-for-all approach, so it is not possible to ascertain whether taxonomic frequency is solely responsible for these results.

As predicted, clustering for parallel CMC groups was significantly lower than face-to-face groups and individuals, which we suppose to be due to the possibility for simultaneous contribution. So, despite the equivalent recall for face-to-face and parallel CMC groups, this data provides the strongest evidence that group members in these conditions approached the task differently. Face-to-face group members converged their efforts to co-ordinate recall by category, whereas parallel CMC group members recalled more independently.

For semantic recall, we analysed the extent to which group members clustered words by spelling, by counting the number of successive words with the same third letter following the digraph prompt. e.g. break, breaks, breed. Each third letter was designated as a category and we counted the number of words that followed a word, hence break, breaks, breed, bring, brine was counted as 3 instances from 2 categories. We then applied the ARC formula (incorrect items and instance repetitions were not included).

A mixed ANOVA (group, individual) demonstrated significant main effects, $F(1,17) = 66.694$, p = .001, $\dot{\eta}^2 = .797$, (within subjects) and $F(1,17) = 56.183$, p $< .001$, $\dot{\eta}^2 = .768$, (between subjects). Paired t-tests revealed that face-to-face groups clustered more words than parallel CMC groups, $t(17) = -8.167$, p $< .001$, $d = 2.05$.

Similar to episodic recall, this suggests that face-to-face group members co-ordinated their recall.

Independent t-tests demonstrated that face-to-face groups clustered more items than nominal individuals, $t(69) = -2.105$, p = .039, $d = 0.63$. Further, nominal individuals clustered more items than parallel CMC groups, $t(69) = 3.215$, p = .002, $d = -0.96$. T-tests comparing parallel CMC individuals with nominal individuals were non-significant, $t(105) = -.109$, p = .914, $d = -0.02$ These findings therefore provide mixed support for our hypotheses. In face-to-face semantic recall, higher clustering aligns with the notion of retrieval strategy disruption; in co-ordinating recall, group members recalled fewer items overall. Lower clustering for parallel CMC groups compared to nominal individuals and face-to-face groups suggests that parallel CMC group members may work more independently to recall. Further, equivalent clustering between parallel CMC individuals and nominal individuals suggests that parallel CMC individuals are able to utilise personal retrieval strategies.

Time

All groups were allowed the same length of time for recall. It is likely that collaborative groups need more time to recall than nominal groups because collaborative group members spend time taking turns and reading each others' contributions. Therefore, it is possible that lower collaborative recall could be due to time limitations rather than collaborative inhibition. To ensure that the time we provided for recall was sufficient, we analysed output at 2-minute intervals throughout the trial. We performed paired sample t-tests for total items recalled in the first and last 2-minute intervals for episodic and semantic recall. Table 2 displays the items recalled in each 2-minute interval. For episodic recall, all tests demonstrated a significant reduction in output during the last 2-minute interval; nominal, $t(17)=$

12.973, p < .001, d = 4.69, face-to-face, $t(17)$ = 10.629, p < .001, d = 3.55, and

parallel CMC, $t(17)$ = 6.685, p < .001, d = 2.84.

For semantic recall, all tests also demonstrated a significant reduction in the

last 2-minute interval; nominal, $t(17)$ = 8.932, p < .001, d = 2.49 face-to-face, $t(17)$ =

10.000, p < .001, d = 2.58 and parallel CMC, $t(17)$ = 8.914, p < .001, d = 2.49. These

findings show that available time per participant is not a limit on the number of words

being recalled by the end of the recall period.

Experiment 2

Experiment 1 has provided evidence that semantic retrieval can suffer from

collaborative inhibition and CMC can improve collaborative semantic recall

compared to face-to-face interaction. Experiment 2 was designed to extend these

findings in two main ways: 1) to examine collaborative inhibition in a different and

more complex semantic recall task, (namely constructing words from a set of letters in

a Scrabble task) 2) to examine the impact of turn-taking in CMC. We now turn our

attention to discuss the nature of the task and the anticipated implications for

collaborative recall and CMC.

The Scrabble paradigm and semantic recall

In the "scrabble" paradigm, subjects are asked to generate words from a set of

letters presented in a random order; there is no previous study phase, hence subjects

must recall words from semantic memory, cued by the available letters (Cansino,

Ruiz, & Lopez-Alonso, 1999; Payne, Duggan & Neth, 2007). The Scrabble task

shares characteristics with the semantic task used in Experiment 1 (no specialised

knowledge[2] and the potential for idiosyncratic retrieval strategies). Further, the task is

more complex than the previous task as words must be generated from a fixed set of

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[2] Specialised knowledge is not required for the Scrabble task, however people that play Scrabble or other word games may possess an advantage over others.

letters. Hence, in addition to the semantic memory search for items, individuals can mentally rearrange the letters to provide a wide range of different cues (adding a strategic problem solving component). Additionally they might have to filter words that require non-prompt letters. We predict that this increased complexity will increase the likelihood of disruption.

Cyclic CMC. In Experiment 2, we extended our exploration of CMC in semantic recall to examine "cyclic" CMC; a turn-taking procedure where only one member can contribute at a time, and where turns rotate for the duration of the trial. Some studies utilising episodic face-to-face turn-taking have found inhibitory effects (Basden et al. 1997, Experiments 1-2); others have found equivalent collaborative and nominal group recall (Basden et al., 1997, Experiments 3-4; Wright & Klumpp, 2004). The factors that differentiated these studies were the way in which recall was organised within the turn taking protocol; recalling from large categories, providing category names at recall (Basden et al., 1997) and seeing others' contributions (Wright & Klumpp, 2004) caused inhibition, whereas recalling non-overlapping parts of a list, organising by category (Basden et al., 1997) and preventing group members from seeing each others' answers (Wright & Klumpp, 2004) removed inhibition.

We predict that cyclic CMC groups will recall less than parallel CMC groups because individuals will experience periods when they are prevented from contributing. Alternatively, we predict that cyclic CMC may reduce collaborative inhibition relative to face-to-face collaboration for a number of reasons: 1) the pressure to contribute implicit in turn taking approaches might increase group member recall (Thorley & Dewhurst, 2007)[3], 2) during a group member's recall, other group members are prevented from contributing, so the group member enjoys an

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[3] Although Thorley and Dewhurst (2007) predicted that group pressure would increase episodic group recall, their results found no difference between free-for-all collaborative recall and face-to-face turn taking.

uninterrupted period of retrieval, 3) Although group members are likely to attend to others' contributions whilst waiting for their turn, and must if they are to avoid repetitions, the physical separation from group members and relief from auditory presentation of items may allow less strategy disruption. Hence:

- Cyclic CMC will reduce collaborative inhibition in semantic recall (Nominal > Parallel CMC > Cyclic CMC > Face-to-face)

Further, our hypotheses for the subsidiary analyses are as follows:

Instance repetitions. Whilst group members may be disrupted when turn taking, cyclic CMC allows group members to ignore each others' output or partially attend:

- (Nominal > Parallel CMC > Cyclic CMC > Face-to-face)

Clustering. Cyclic CMC group members will be free to utilise personal retrieval strategies, uninterrupted upon their turn. We expect that group members will influence each other, resulting in more clustering than parallel CMC groups, but less than individuals and face-to-face groups:

- Clustering will be higher for face-to-face groups than individuals, cyclic and parallel CMC groups (Face-to-face > Individual > Cyclic > Parallel)

Similarly, we anticipate this will be reflected in the individual CMC contributions:

- Clustering will be higher for nominal individuals than cyclic and parallel individuals (Individual > Cyclic individual > Parallel individual)

Method

Participants and Design

One hundred and forty four native English speakers from the University of Manchester with a mean age of 23.5 (82 males, 62 females) volunteered to take part in the study. Participants were recruited through an advertisement placed on the Research Volunteering section of the university website. The incentive for

participation was a £5 high street shopping voucher. A between-subjects design was employed, where each group completed one of four conditions (Nominal vs. Face-to-Face vs. Parallel vs. Cyclic). After agreeing to take part in the study, participants were randomly allocated to a triad and experimental condition with no regard to gender or time slot. In total, 54 triads took part in the experiment. Seating arrangements were the same as in Experiment 1 and groups in the cyclic condition were seated in the same way as parallel groups. A series of pilot tests were conducted to assess an appropriate length of time for recall, in which participants recalled with no time restrictions. The tests revealed that 15 minutes appeared to be adequate for participants to be approaching exhaustion.

Materials and Apparatus

12 random letters were generated using the random letter sequence generator (http://www.dave-reed.com/Nifty/randSeq.html). The potential yield of the set of letters was checked using a program called *Scrabble Buddy* (http://boulter.com/scrabble/). Scrabble Buddy generated 467 words, which included proper nouns, acronyms and further words, which were still unrecognised. This list was presented to a single student participant who was asked to identify which words they recognised. This process yielded a potential of 261 words that could be generated from the set, which represents a realistic upper bound on recall performance if time were unlimited. The 12 letters were presented to the participants via a PowerPoint slide and remained on screen throughout the retrieval trial. The letters were displayed in bold black 44pt Arial font and were presented centred on a white background. The same software that was used in Experiment 1 was used.

Procedure

The procedure was adapted from Experiment 1. Participants were issued with instructions, which were tailored according to their collaborative condition. All groups were asked to generate as many English words as possible in 15 minutes with a minimum of 2 letters, to only use a letter once in any given word and to not generate acronyms and proper nouns, as they would not be counted. For groups in the cyclic condition, participants were informed of the turn-taking procedure: one group member recalls at a time and the turn rotates when no contribution has been made for 20 seconds, a protocol that continues for the duration of the trial.

Results

Scoring

The number of correctly generated words was computed for each trial in each generation condition (Nominal, Face-to-face, Parallel, and Cyclic), according to the specified criteria (no proper nouns, acronyms, misspelled or incorrect words). The number of instance repetitions and incorrect items were computed in the same way as Experiment 1. Table 3 displays the mean scores for groups and individuals (nominal, parallel CMC and cyclic CMC) for correct items, instance repetitions and clustering. Alpha levels and Bonferroni adjustments were made in accordance with the protocols for Experiment 1.

Correct items

A one-way between-subjects ANOVA (Nominal vs. Face-to-face vs. Parallel vs. Cyclic) for the total number of words generated revealed a significant main effect, $F(3,44) = 29.846$, $p < .001$, $\acute{\eta}^2 = .671$. Further, planned comparisons revealed that nominal groups generated more correct items than face-to-face groups, $t(22) = 6.282$,

p < .001, $d = 2.63$, parallel CMC groups, $t(22) = 4.001$, p = .001, $d = 1.68$ and cyclic

CMC groups, $t(15) = 7.388$, p < .001, $d = 2.90$. (For the latter comparison, Levene's

test indicated unequal variances, ($F = 6.498$, p = .018), so degrees of freedom were

adjusted from 24 to 15.) These results replicate the findings from Experiment 1 and

confirm our hypothesis in a different semantic recall task.

We also predicted that parallel CMC groups would generate more words than

cyclic CMC and face-to-face groups. A planned comparison for parallel vs. cyclic,

face-to-face was significant, $t(33) = 4.794$, p < .001, $d = 1.70$. However, cyclic CMC

appeared to offer no benefit over face-to-face collaboration. Given that the main

difference in design between parallel and cyclic CMC was the turn-taking protocol,

we attribute the lower recall to this.

Instance repetitions

The instance repetitions data confirmed our hypotheses and replicated the

findings presented in Experiment 1; nominal groups duplicated more items than

collaborative groups. A one-way between subjects ANOVA (Nominal vs. Face-to-

face vs. Parallel vs. Cyclic) demonstrated a significant effect of retrieval condition,

$F(3,50) = 43.621$, p < 0.001, $\dot{\eta}^2 = .72$. A planned comparison for nominal vs. face-to-

face, parallel, cyclic demonstrated that nominal groups generated more instance

repetitions than collaborative groups, $t(50) = 9.631$, p < 0.001, $d = 2.51$.

A planned comparison for face-to-face vs. parallel, cyclic was also significant,

$t(50) = 4.878$, p < 0.001, $d = 1.66$, demonstrating that groups using parallel and cyclic

CMC generated more instance repetitions than groups collaborating face-to-face.

Finally, we predicted that groups using parallel CMC would generate more instance

repetitions than cyclic CMC and face-to-face groups. A planned comparison for

parallel vs. face-to-face, cyclic was significant, $t(50) = 5.914$, p < 0.001, $d = 1.62$,

providing support for this hypothesis. These findings provide further evidence that

CMC allows partial attendance to other group members' output. Further, whilst there was no difference in overall recall between face-to-face and cyclic CMC groups, these results indicate that cyclic CMC group members also approached recall differently to face-to-face group members by attending less to incoming items.

Clustering

Similar to Experiment 1, we analysed the extent to which group members clustered words by spelling. In this instance we measured the extent to which group members clustered words starting with the same letter, e.g. *fat, fast, baste, set* was counted as 1 instance across 3 categories. We then applied the ARC formula, and similar to Experiment 1.

A one-way between-subjects ANOVA (Nominal individuals vs. Face-to-face vs. Parallel vs. Cyclic) was non-significant, $F(3,74) = 1.478$, p $= .228$, $\dot{\eta}^2 = .057$. Further, a one-way between subjects ANOVA (Nominal individuals vs. Parallel individuals vs. Cyclic individuals) was also non-significant, $F(2,117) = .605$, p $= .548$, $\dot{\eta}^2 = .010$.

Focussing entirely on initial letters seems to underestimate orthographic influence of one recalled word on the next. Because participants needed to check and rearrange letters when generating words, it is likely that participants were influenced by letters in other positions in the word. To address this, we conducted an additional analysis where we counted successive words with common bigrams, irrespectively of their position in the word, and calculated the proportion of words recalled that shared a bigram with their predecessor. Thus, if the complete recall protocol was *meat, beat, earn, turn*, it would be scored as 0.75; *meat beat, earn, tune* would be scored as 0.5. This proportion score is not exactly a "clustering" score, but the underlying principle is so similar that we will refer to it that way.

A one-way between subjects ANOVA (Nominal individuals vs. Face-to-face vs. Parallel vs. Cyclic) on the proportion scores revealed a significant main effect, $F(3,70) = 3.555$, p = 0.19, $\acute{\eta}^2$ = .132. We predicted that clustering for face-to-face groups would be higher than CMC groups and nominal individuals, however a planned comparison was non-significant, $t(70)$ = .860, p = .393, d = -0.461 . Clustering therefore cannot account for retrieval strategy disruption in this instance.

As predicted, nominal individuals did cluster more items than CMC groups as a planned comparison for nominal individuals vs. parallel, cyclic was significant, t70) = 2.965, p = .004, d = 1.771, which demonstrated that group members are recalling in different orders to individuals working alone. There was no difference in clustering between parallel and cyclic CMC groups, $t(70)$ = -1.549, p = .126, d = -1.289, which is surprising given that cyclic CMC group members are free to recall in their preferred order once given the opportunity to recall. It may therefore be the case that in the time they are blocked from recalling, seeing others' contributions disrupts their natural order and they are unable to recover from it in the time they have for recall.

Finally, to compare individual clustering in the nominal and CMC conditions, a one-way between subjects ANOVA (nominal individuals vs. parallel individuals vs. cyclic individuals was significant, $F(2,110)$ = 3.662, p = .029, $\acute{\eta}^2$ = .064. As predicted, a planned comparison for nominal individuals vs. parallel/cyclic individuals demonstrated higher clustering for nominal individuals, $t(108)$ = 2.633, p = .010, d = 1.380, however clustering for parallel and cyclic individuals was equivalent, $t(108)$ = -.496, p = .62, d = -0.145. This further demonstrates that group members still influenced each others' contributions, despite the increased opportunity to work independently.

Time

As for Experiment 1, we conducted analyses of time to ensure that differences in recall could be attributed to collaborative inhibition rather than time limitation. Paired sample t-tests for total items generated in the first and last 3-minute intervals were conducted. Table 4 displays the mean performance across all 3-minute intervals. Tests across all conditions were significant; nominal, $t(12) = 8.807$, p < .001, $d =$ 2.69, face-to-face, $t(14) = 6.853$, p < .001, $d = 2.55$, parallel CMC, $t(17) = 11.195$, p < .001, $d = 2.92$, and cyclic CMC, $t(16) = 6.773$, p < .001, $d = 1.57$. Whilst outputting was still fairly substantial in the last 3 minutes of each condition, all had diminished greatly since the first 3 minutes, suggesting that time per individual is not limiting the number of items retrieved during the final 3 minutes. Thus, we are confident in interpreting our results in accordance with inhibitory explanations.

General Discussion

Across both experiments, we found support for our main hypotheses. Collaborative inhibition was present in both episodic and semantic recall and groups collaborating via parallel CMC were able to recall more than face-to-face groups in semantic recall. For episodic recall in Experiment 1, lower face-to-face recall compared to nominal groups replicates typical findings of collaborative inhibitory effects in recall (e.g. Andersson & Ronnberg, 1995; Basden et al., 1997; Meudell et al., 1995; Weldon & Bellinger, 1997). In Experiments 1 and 2, lower collaborative group recall demonstrates new evidence for collaborative inhibition in semantic recall. Inhibitory effects were also demonstrated in computer mediated communication. In Experiment 1, parallel CMC recall was equivalent to face-to-face recall in the case of episodic memory but was greater than face-to-face in the case of semantic memory. In Experiment 2, computer mediated communication improved recall relative to face-to-face collaboration when groups interacted via parallel CMC

but not cyclic CMC. We conclude that semantic recall can be inhibited by collaboration and that parallel CMC can help to alleviate inhibitors.

Lower semantic recall for collaborative compared to nominal groups is a relatively novel finding. Our results most closely align with Weldon's (2000) preliminary results, where a collaborative deficit was present in the recall of US states and map reconstruction tasks. Similarly, our tasks were "uncued" in Weldon's sense (uncued beyond the digraph or letter-set constraint) - retrieval for English words is likely to differ for each individual, therefore the findings are consistent with Basden et al.'s (1997) retrieval strategy disruption hypothesis. A factor that may further differentiate the inhibition present in our tasks from others where inhibition was absent (Andersson & Ronnberg, 1996; Weldon, 2000) is the extent to which our tasks were quantifiable and bounded. In episodic tasks, recall material is well defined and individuals know the amount they can potentially recall. Whilst the number of English words a person knows is finite, it is highly unlikely they are aware of how many words they know. Thus, the absence of target-specific responses (e.g. questions), or a quantifiable target to recall may influence how much individuals actually recall. Further, individuals may also be more likely to loaf when collaborating if they do not know how much they are capable of recalling. We did not specifically test for loafing; however, further research could explore this possibility for these types of tasks.

Parallel and cyclic CMC provided further evidence that collaborative recall can be inhibited in semantic retrieval and extended research on inhibitory effects in episodic recall. Our findings for parallel CMC episodic recall echo Ekeocha and Brennan's (2008), which also found equivalent face-to-face and CMC recall. Whilst our design and measures differed, our findings were similar in that face-to-face and CMC groups approach the recall tasks differently. Ekeocha and Brennan (2008)

found that face-to-face groups filtered out each others' items, (as a group they failed

to incorporate or rejected items), whereas CMC group members self-filtered (instead

of communicating items to the group, they withheld or failed to retrieve items). We

did not measure filtering, but our analyses for instance repetitions and clustering

demonstrated differences at the individual and group levels in a similar manner.

Higher numbers of instance repetitions generated by parallel CMC groups indicates a

tendency for group members to attend less to each others' contributions, and higher

clustering for face-to-face compared to parallel CMC groups demonstrates a tendency

for face-to-face group members to co-ordinate recall.

One might characterise the CMC technology used in our studies as an

"implicit coordination" technology (Lowry, Dean, Roberts & Marakas, 2009). These

authors explored the use of Computer Supported Collaborative Work to help groups

of user interface evaluators to coordinate their fault-finding reports. They argued that

shared message windows of the kind our study utilised enable groups to adaptively

manage their collaboration, gaining advantages over more explicit division of labour

as well as over uncoordinated individual activity. Future research might usefully try to

tease apart the exact technological conditions and affordances that contribute (and

might further extend) the advantages we have reported for collaboration in the parallel

CMC condition (e.g. it is possible that the size of the shared communication window

exerts some important effects).

For semantic recall, the instance repetitions and clustering data also

demonstrated different approaches to recall for face-to-face and CMC groups. Higher

instance repetitions and lower clustering for parallel CMC compared to face-to-face

groups reinforced the notion that parallel CMC may reduce retrieval strategy

disruption. Cyclic CMC groups demonstrated similar findings for instance

repetitions, but overall recall was not superior to face-to-face recall. Thus cyclic

CMC changed retrieval strategies but did not reduce disruption. We suggest that the possibility for simultaneous contribution in parallel CMC explains this discrepancy. Whilst cyclic CMC group members did attend less to each others' contributions than face-to-face group members, they did not "ignore" each other as much as parallel CMC group members (who generated more instance repetitions). Type of CMC had no effect on the extent to which group members disrupted each others' order of recall, as clustering for parallel and cyclic CMC groups and was equivalent at the group and individual levels. Thus, we believe that the turn-taking process in cyclic CMC was responsible for lower overall recall; despite being able to benefit from periods of uninterrupted recall, the time spent waiting was too disruptive for group members to benefit. One limitation of this work is that we did not measure the contributions for individual face-to-face group members so as to make similar comparisons for face-to-face groups.

Part of our motivation for examining semantic recall came from the evidence of productivity loss in the brainstorming literature. Whilst we believe our results can be explained by retrieval strategy disruption, we are not ruling out productivity losses as causes of reduced collaborative semantic recall. We did not take measures of production blocking, evaluation apprehension and social loafing, but recognise their potential to impact semantic recall (especially given the generational style of the tasks used). Therefore, further research could explore these factors in semantic recall. Additionally, the work could also be developed to examine whether recall can benefit from collaboration if group members are encouraged to exploit the features of CMC. For instance, if group members alternate their attention between personal and group output, collaborative inhibition may be reduced further, eliminated altogether or recall may even surpass nominal groups.

Overall, the results have challenged often-made assumptions as well as the limited existing work on semantic memory: in contradistinction to this prior work, collaborative inhibition does affect semantic recall. Further, parallel CMC has been shown to improve collaborative semantic retrieval, demonstrating that it is possible, through socio-technical design, to reduce collaborative inhibition. More work is needed to develop an understanding of this potential.

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Tables

Experiment 1

Table 1 Mean scores for analyses of nominal and collaborative groups in episodic and semantic recall

Condition	Episodic		Semantic	
	M	*(SD)*	*M*	*(SD)*
Correct items				
Nominal	47.30	5.51	80.70	23.99
Face-to-face	40.50	7.16	60.70	10.65
Parallel (CMC)	42.00	8.13	69.40	16.49
Instance repetitions				
Nominal	36.94	12.28	31.83	13.62
Face-to-face	6.22	5.95	3.61	2.59
Parallel (CMC)	8.28	7.58	13.72	10.68
Clustering scores				
Individual	0.42	0.26	0.31	0.28
Face-to-face	0.48	0.22	0.46	0.18
Parallel (CMC)	0.25	0.20	0.09	0.19
Parallel individuals	0.43	0.27	0.31	0.24

Table 2 Total mean output per 2-minute interval in episodic and semantic recall

	2		4		6		8	
Condition	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*
Episodic								
Nominal	47.24	12.19	22.41	11.48	10.76	6.69	5.00	3.69
Face-to-face	27.61	9.11	11.44	5.66	5.17	3.17	3.72	2.72
Parallel	36.22	12.82	10.89	6.42	7.39	7.31	5.83	8.08
Semantic								
Nominal	44.76	14.66	25.76	15.91	18.29	8.18	13.88	9.62
Face-to-face	25.50	7.19	15.28	4.07	13.56	4.48	9.94	4.61
Parallel	35.39	11.01	20.79	7.40	15.39	5.87	13.72	5.52

Experiment 2

Table 3 Mean scores for analyses of nominal and collaborative groups

	Correct items		Instance repetitions		Clustering (Starting letter)		Clustering (Bigraphs)	
Condition	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*
Nominal	120.08	21.36	62.77	12.99				
Nominal individual					0.23	0.24	0.46	0.15
Face-to-face	74.36	12.36	5.18	4.67	0.26	0.13	0.31	0.13
Parallel	91.55	10.90	30.50	16.47	0.10	0.12	0.20	0.04
Parallel individual					0.18	0.27	0.29	0.13
Cyclic	73.62	7.60	14.4	9.14	0.21	0.22	0.28	0.08
Cyclic individual					0.16	0.24	0.27	0.11

Table 4 Total mean output per 3-minute interval

	3		6		9		12		15	
Condition	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*
Nominal	58.23	15.36	38.85	12.15	34.31	8.64	24.46	6.92	25.69	7.44
Face-to-face	37.47	14.13	23.13	9.13	14.80	9.10	11.87	7.39	9.73	5.06
Parallel	51.61	15.70	33.50	12.83	23.50	8.26	19.11	5.12	16.78	6.16
Cyclic	27.65	7.77	23.71	6.07	20.00	6.36	18.06	5.62	15.18	8.06