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# Collaborative Facilitation and Collaborative Inhibition in Virtual Environments

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**Abstract:** Worldwide, organizations and small and medium-sized enterprises have already disruptively changed in many ways their physiological inner mechanisms, because of information and communication technologies (ICT) revolution. Nevertheless, the still ongoing COVID-19 worldwide emergency definitely promoted a wide adoption of teleworking modalities for many people around the world, making it more relevant than before to understand the real impact of virtual environments (VEs) on teamwork dynamics. From a psychological point of view, a critical question about teleworking modalities is how the social and cognitive dynamics of collaborative facilitation and collaborative inhibition would affect teamwork within VEs. This study analyzed the impact of a virtual environment (VE) on the recall of individuals and members of nominal and collaborative groups. The research assessed costs and benefits for collaborative retrieval by testing the effect of experimental conditions, stimulus materials, group size, experimental conditions order, anxiety state, personality traits, gender group composition and social interactions. A total of 144 participants were engaged in a virtual Deese-Roediger-McDermott (DRM) classical paradigm, which involved remembering word lists across two successive sessions, in one of four protocols: $I$-individual/nominal, $II$- nominal/individual, $III$- nominal/collaborative, $IV$-collaborative/nominal. Results suggested, in general, a reduced collaborative inhibition effect in the collaborative condition than the nominal and individual condition. A combined effect between experimental condition and difficulty of the task appears to explain the presence of collaborative inhibition or facilitation. Nominal groups appeared to enhance the collaborative groups' performance when virtual nominal groups come before collaborative groups. Variables such as personality traits, gender and social interactions may have a contribution to collaborative retrieval. In conclusion, this study indicated how VEs could maintain those peculiar social dynamics characterizing the participants' engagement in a task, both working together and individually, and could affect their intrinsic motivation as well as performances. These results could be exploited in order to design brand new and evidenced-based practices, to improve teleworking procedures and workers well-being, as well as teleworking teamwork effectiveness.

**Keywords:** virtual dynamics; collaborative inhibition; collaborative facilitation; DRM paradigm; virtual teamwork

**Highlights**

- The group condition affects the collaborative inhibition and the collaborative facilitation effects, even when the communication between subjects is mediated only by a virtual environment (VE).
- The study reveals a reduced collaborative inhibition effect in VEs.
- Collaborative inhibition and facilitation dynamics appear as affected by the nature of the "virtual setting" as well as by the physical isolation of the subject.
- The features of the stimuli (i.e., abstract versus concrete words) appear to affect both the collaborative facilitation as well as inhibition effects.
- Men and women show a different effectiveness in the different conditions, and as a consequence a different susceptibility to the "virtuality" of the task.

## 1. Introduction

Many activities or tasks that take place in both organizational and social contexts require collaboratively recalling information [1]. This collaborative process may be influenced by the medium (face-to-face—FtF communication vs. computer-mediated communication—CMC) used to interact and communicate information [2]. All over the world organizations have already changed their procedures in a disruptive way due to the information and communication technology (ICT) revolution. Moreover, the global emergency COVID-19, which is still ongoing, has certainly fostered a wide adoption of teleworking methods [3] to cope with the new social organization in the world required by the pandemic. From a psychological point of view, understanding the real impact of VEs on the dynamics of teamwork [4,5], in terms of collaborative inhibition and collaborative facilitation, has become a core issue.

The collaborative recall paradigms were typically developed to evaluate the costs (i.e., collaborative inhibition) and benefits (i.e., collaborative facilitation) of remembering in a group context (e.g., the percentage of studied stimulus accurately recalled) [6]. Within this approach, the majority of the studies have assessed the impact of recalling with someone else, comparing the results of collaborative groups to the outcomes of nominal groups (i.e., the sum of the outputs of non-interacting individuals) or individuals alone [7,8]. Nokes-Malach et al. [9] stated that collaborative inhibition occurs if the individual underperforms what he/she could obtain working alone while collaborative facilitation is identified when an individual performs better in the group compared to what he/she would do alone. More specifically, in their review, the authors highlighted that increased memory coordination costs and retrieval disruption strategy are the main factors related to collaborative inhibition while building common ground among group members, activities/tasks gaining multiple perspectives and shared information related to the activities/tasks are key mechanisms associated with collaborative facilitation [9]. Through a systematic review [10], other researchers tested variables predicted by the retrieval disruption strategy (i.e., group size, type of retrieval, type of memory test, study materials, social relationship, category size, number of study/test phases, encoding task) in collaborative inhibition which was greater for larger groups, turn-taking retrieval and groups of strangers while it was weaker for forced-order tests and story-like materials [10]. This review also focused on post-collaborative memory. Results suggested, on one hand, a benefit on subsequent individual retrieval from prior collaborative retrieval and, on the other hand, a possible contribution of retrieval inhibition on collaborative inhibition [10].

Based on the literature of collaborative recall and computer-supported collaborative learning (CSCL), our study aims to investigate the impact of a VE on the recall of individuals and members of nominal and collaborative groups through a Virtual DRM classical paradigm. The research seeks to answer a key research question: does a VE such as a chat line mitigate the effect of collaborative inhibition? To answer this question, this study evaluated costs and benefits for collaborative retrieval by testing the effect of experimental conditions (individual, nominal and collaborative condition), stimulus materials, group size, order of experimental conditions, state of anxiety and personality traits, gender group composition and social interactions.

### 1.1. Evidence from Collaborative Memory Tasks

The collaborative inhibition and facilitation effects have been a focus of studies on collaborative memory tasks. Some of them have applied the DRM paradigm [11] that was also used in this study. In the DRM paradigm, individuals learn lists with semantically related words (studied words: e.g., apple, orange, berry etc.). The most "common" word of the category is removed. This omitted word is called "critical lure" (e.g., fruit). With DRM paradigm, it is possible to evaluate the false recall of both the critical lure, as well as of other words (i.e., non-studied words) during collaboration.

Studies that have assessed collaborative recall performance indicated mixed results [12]. For instance, some experiments (experiment 1 and 2) adopting the Deese-Roediger-McDermott (DRM) paradigm found that collaborative groups performed worse than nominal counterparts due to disorganized retrieval [13]. Another research indicated that collaborating groups performed better than individuals by recalling more presented words and they resulted in less false memories than the nominal condition [8]. More recently, a study by Saraiva et al. [12] showed that the recall of the presented words was greater for the nominal condition than collaborative condition but this latter condition resulted in less false memories than the nominal condition.

Some researchers explain such contrasting results through different encoding strategies which people apply to categorize lists of studied words. Using category lists (concrete words), Olszewska and Ulatowska [14] evaluated the influence of the encoding strategy (imagery, word-whispering, control) on memory performance through four experiments that differed in the type of recovery (recall, recognition) and duration of the encoding (self-paced, fixed duration). Overall, results suggested a more accurate memory performance for imagery encoding than word-whispering encoding. A remarkable result was related to the control group that showed a tendency to be more accurate. This result was explained by the researchers through Paivio's dual coding theory [15] that argues that it is possible to spontaneously evoke mental images of encoded concrete items and, therefore, the resulting verbal and visual codes could be exploited during retrieval. Unlike the DRM paradigm [11] which may use both abstract and concrete word lists, the latter study by Olszewska and Ulatowska [14] used categorical study lists that include only concrete words that are equally easy to imagine. As suggested by Kirschner et al. [16], *"the complexity of the task was identified as an important factor for determining whether collaborative learning will or will not be effective and/or efficient as compared to individual learning"* (p. 39). In particular, an individual will be able to benefit from collaboration with others the more complex the learning task will be. In this case, the greater intrinsic cognitive load of the complex task will be reduced by its division among group members and, therefore, collaborative learning might lead to better results than individual learning. On the contrary, groups might perform as individuals or worse when the task complexity decreases [16].

Another variable that may influence false recall is the group size. Using DRM lists as stimuli, Thorley and Dewhurst's study [17] aimed to examine the effects of group size (individuals, pairs, trios and quartets) and group pressure (high pressure—turn taking recall; low pressure—free for all; nominal recall) on critical lures, nonstudied intrusions and studied words recall. Results showed that, regardless of group pressure, critical lures, nonstudied intrusions and studied words increased with group size. High pressure group members falsely recalled more critical lures and intrusions. In accordance with collaborative inhibition, nominal group members recalled more studied words than individuals of free for all and turn taking groups.

With regard to the effect of prior collaboration on subsequent individual recall, findings of the study mentioned above [17] showed that only participants who collaborated in turn taking (high pressure group) later recalled comparable levels of critical lures in an individual trial. More recently, Harris et al. [7], using word lists, assessed the recall accuracy (items recalled in error) and recall completeness (study material accurately recalled) in turn-taking and consensus groups (during and after collaboration). Regarding the recall accuracy, results showed that only consensus groups, compared to the nominal and rotational groups, brought advantages, both during and after collaboration. Authors believed that this benefit in consensus groups was due to a group error-checking process. As regards the recall completeness, findings indicated that consensus and turn-taking groups resulted in collaborative inhibition (i.e., both recalled lesser words from the list compared to nominal groups). After the collaboration, both groups increased individual recall. Authors argued that this benefit in post-collaboration could be due to the reexposure to list items.

Individual variables, such as stress levels and sex, have also been studied using the DRM paradigm. For instance, the two studies of Smeets et al. [18] were addressed to analyse the effect of stress in the recall of false memories in the DRM paradigm, and whether such effect might be modulated by sex. Results highlighted that neither the "stress group" nor the high cortisol responders showed a greater number of false recalls and false recognition of critical lures than the control group and the low cortisol responders. Moreover, while sex did not modulate the effect of stress on the performance, studies suggested that, regardless stress, men evoked more extra list words than women.

### 1.2. Collaborative Inhibition and Collaborative Facilitation in Computer-Mediated Communication

Few studies have examined whether computer-mediated communication (CMC) may mitigate or increase collaborative inhibition in recall. Ekeocha and Brennan's study [19] aimed at analysing the possible source of the productivity loss in groups collaborating through different media (FtF or electronic groups) compared to nominal groups and at studying the possible consequences of group recall on the subsequent individual recall. Results showed that group recall products compared to the individual pre-group recall products were of higher quality, suggesting that groups and not individuals have mechanisms for error checking. It was found that nominal groups outperformed compared to spontaneously interacting groups. The study did not find any differences between FtF groups and electronic groups with respect to recalled propositions (i.e., comparable performance) but differences in the type of filter of their contributions (more group-filtering with FtF groups and more self-filtering with electronic groups). Finally, the study showed that the individual post-group recall was improved by the experience of having recalled in an FtF group, but not in an electronic group. Authors considered that the non-verbal cues, in order to propose and ratify contributions to the group product, of the FtF communication supported the enhancement in the post-group recall.

More recently, Hinds and Payne conducted two studies (study 1 [2] and study 2 [1]) that aimed to assess whether the semantic recall is sensitive to collaborative inhibition, to test whether CMC may enhance collaborative recall (study 1 and study 2), and to verify whether a subsequent individual semantic recall may be increased by a previous collaboration FtF or via CMC (study 2). About study 1 [2], results showed that collaboration may inhibit semantic recall, in addition to episodic recall, and that collaborative inhibition may be mitigated by parallel CMC, which could decrease retrieval strategy disruption. Similar to the results of the study by Ekeocha and Brennan [19], study 1 [2] found a different approach to recall tasks for FtF groups (tendency to coordinate recall—clustering) and parallel CMC groups (tendency to participate less in each other's contributions—repetitions). In study 2, Hinds and Payne [1] identified a collaborative inhibition of semantic recall in both FtF and parallel CMC groups compared to nominal groups. Participants who had cooperated in the two previous recalls showed a higher individual recall at the third trial than those who had always individually recalled in the three trials. In contrast to study 1 [2], study 2 found no difference between recall in FtF and parallel CMC groups, so the latter did not benefit collaborative recall. However, similarly to study 1 [2] and Ekeocha and Brennan's study [19], a difference had emerged between the FtF and parallel CMC approaches to recall (i.e., attention to the contributions of others and organisation).

### *1.3. Effects of Individual Characteristics: Personality Traits, State Anxiety and Gender on Collaborative Learning*

Other elements to be considered when analysing collaborative learning are individual characteristics [20]. Variables that may influence online learning are personality traits and state anxiety. Few studies have described the relationship between online learning and personality traits, showing contradictory findings [21]. One study reported that people with lower levels of extraversion and higher levels of openness and conscientiousness tend to prefer online training compared to participants who prefer traditional FtF teaching methodologies [22]. In contrast, a study found that, in the context of CSCL, extraverts are active participants [23]. Another research [24] pointed out that individuals with higher levels of openness and conscientiousness tend to choose traditional FtF teaching methodologies compared to those who prefer online settings. Finally, one study showed that even if people slightly differ in their personality traits, these differences did not explain the variance in learning within online or FtF contexts [21]. With regard to the state anxiety, several studies indicated that people can learn in online settings if they have low levels of anxiety [21,25,26].

The effects of gender grouping in group performance during collaborative learning settings have been explored in some studies [27]. So far the results have been mixed. Some researchers showed that single-gender grouping works better than mixed-gender grouping, since participants of single-gender grouping are more focused on the purpose of the task [28,29]. On the contrary, other contributions highlighted that in mixed-gender groups individuals' knowledge tends to diverge more than in single-gender groups, and these processes should be important elements for positive results in collaborative learning [30]. For some authors, having a majority of females in a group is one of the best predictors of successful group outcomes [31], whilst other researchers suggest that having a female-only and a balanced-gender group are two types of good grouping interventions for CSCL [32]. Little research focused on the effects of gender grouping on female and male participants' learning in VEs, and these studies showed controversial results [32]. Some studies indicated that male participants in mixed-gender groups significantly outperformed compared to female participants in mixed-gender groups [33] or to males in single-gender groups [32]. Females in single-gender groups performed significantly better than those in mixed-gender groups [30] or no statistical difference was found in females among different gender grouping conditions [32]. These different results in the effects of gender grouping on female and male participants learning could be explained by the individual attitudes in collaborative learning. Female participants tended to feel more comfortable in single-gender groups [32,34] or gender-minority grouping [32]. In contrast, male participants in single-gender groups tended to feel significantly more uncomfortable than males in mixed-gender [32,34], gender-balanced, and gender-majority grouping [32].

### *1.4. Effects of Social Processes on Collaborative Learning: The Importance of Social Interaction*

In general, different social processes have been hypothesized to facilitate or inhibit the performance of a group [9]. Considering the mechanisms underlying collaborative facilitation, observational learning appears as a social process that showed positive effects on the collaborative learning [35,36]. Furthermore, the motivation may be increased in a collaborative learning context because the members of the group seem to develop a common ground of shared motivational processes [37]. For what concerns social factors that could contribute to collaborative inhibition, some researchers recognized the process of social loafing as a relevant factor [38,39]. Social loafing occurs when a group's member applies less effort to obtain a goal when he/she works in a group than alone because he/she has the belief that someone else in the group will contribute to the task. Another social process involved in the collaborative inhibition is the sucker effect [40], which occurs when the more productive group's members reduce their individual efforts because they recognize that other co-members did not contribute. Instead, the free-rider effect occurs when the non-contributing members feel that the more productive group's members are doing enough, so they do not need to contribute [41]. Moreover, the social pressure or group conformity [42], and the fear of evaluation from individuals in the group [43,44] can be further mechanisms involved in the collaborative inhibition. Hence, individuals in a group might not share their opinions and solutions, non-participating to the task, fearing a negative evaluation from others [9].

To better understand which variables affect the CSCL, it is necessary to analyze the social interactions among group members if we really want to understand the implications of its use [45]. Several variables (e.g., the size of the group, the composition of the group, the nature of the task, the learning styles) could be important factors which influence the effectiveness of collaborative learning, but all these factors are related to a key variable: the social interaction [46,47]. Such element seems particularly significant in the CSCL, as social interaction is the tool through which participants, verbalizing their opinions, may develop a collective knowledge in order to reach the group's purposes [46]. Participants' interactions are one of the most significant indicators of success in online environments [48]. More specifically, the interaction styles were positively related to the performance of virtual teams [49]. About this, a software called Linguistic Inquiry Word Count (LIWC; [50]) is able to evaluate the content of a social interaction, by coding transcripts on a word-by-word basis, and comparing words with a dictionary divided into 80 linguistic dimensions (e.g., affective terms, cognitive terms, social and communicative processes) [51]. Then, it allows to obtain information about the members of the interaction, as the presence of self-disclosed people is suggested by a high number of words in virtual interactions [52], while the use of negations appears to be related to a cognitive complexity [53]. Moreover, using more third person pronouns appears to enhance a focus on others, and to be related with adaptive coping [53]. Such a software is also applied in this study, to analyze the linguistic content of virtual interactions between members of the groups.

### *1.5. The Present Study*

The study sought to analyze costs and benefits for recall completeness and accuracy of three different experimental conditions: 1) individual, 2) nominal and 3) collaborative condition, using the lists of the DRM paradigm [11], in a VE recently implemented by our lab [54–56]. We focused on the stimulus materials (i.e., list of concrete versus abstract words), the effect of the group size (i.e., individual, dyad, triad, and quartet), and the experimental conditions order (i.e., individual-nominal vs. nominal-individual or nominal-collaborative vs. collaborative-nominal) on the performance. We also investigated the impact of anxiety state and personality traits as well as gender group composition (i.e., same-gender, mixed-gender and gender majority group) on the performance. Finally, we analyzed the social interactions among members of collaborative groups within the VEs.

No previous literature extended the DRM paradigm to study group collaborative inhibition and facilitation within VEs. And no one compared minimal and not minimal group dynamics in order to capture the role of mental schemes and cognitive heuristics which lays beyond the actual communication dynamics. In order to take into account the complexity of real group interactions, we decided to consider all the fundamental experimental factors characterizing the task to build the experimental hypotheses. In particular, the main aim of the study is to verify the magnitude and dynamics of well known cognitive processes (i.e., collaborative inhibition and facilitation) within VEs. A way to answer to this research question is to verify the expectations derived from literature reporting evidences coming from "real" environments (i.e., FtF and classical studies). The following hypotheses have been formulated as extensions of findings coming from real environments, or from different virtual dynamics not related with the DRM paradigm. Nonetheless every hypothesis has never been tested, and reported as follows with sorted by importance:

1. The collaborative facilitation and inhibition, during a DRM task, are present even within a VE (e.g., [2,8,12,13]).

2. The list of abstract words will be more difficult to learn than the list of concrete words even within a VE [14].

3. False recall will increase in relation to group size [17].

4. Prior collaboration will enhance later nominal studied word recognition (e.g., [1,7]).

5. Participants with lower levels of anxiety will perform better than people with higher levels of anxiety, and personality traits will not influence the performance [21].

6. Females will have a better performance in all experimental conditions and they will have a better performance in the gender majority group, while males will perform better in mixed-gender groups (e.g., [18,32]).

7. A greater involvement of participants in the chat will produce better performance in a DRM task [48].

## 2. Method

### 2.1. Participants

A total of 114 participants (50% females) were involved in the study. These participants were of legal age (age: $M = 29.28$, $SD = 10.69$) and their average educational level was 14.66 years, ($SD = 3.95$). All participants were volunteers and recruited through the snowball sampling method.

This study was carried out in full observance of the Guidelines for the Ethical Treatment of Human Participants of the Italian Psychological Association (i.e., AIP). All participants gave informed consent and they could withdraw from participation at any time. All participants fulfilled the questionnaire administered during the study's first phase and none of them withdrew during the experiment.

We conducted a power analysis in order to estimate the optimal sample size for the statistical analysis adopting the equation 1 [57]. Table 1 shows the results.

$$n_b = \left(1 + \frac{1}{K}\right)\left(\sigma \frac{Z_{1-\frac{\alpha}{2}} + Z_{1-\beta}}{\mu_a - \mu_B}\right)^2 \tag{1}$$

with

$$1 - \beta = \Phi(Z - Z_{1-\frac{\alpha}{2}}) + \Phi(-Z - Z_{1-\frac{\alpha}{2}}) \tag{2}$$

and

$$Z = \frac{\mu_A - \mu_B}{\sigma\sqrt{\frac{1}{n_a} + \frac{1}{n_b}}} \tag{3}$$

where $K = \frac{n_a}{n_b}$, $\sigma$ is the standard deviation, $\Phi$ is the standard Normal distribution function, $\Phi^{-1}$ is the standard Normal quantile function, $\alpha$ is Type I error, and $\beta$ is Type II error, meaning $1 - \beta$ is power.

**Table 1.** Sample size estimation to compare two means from two samples with two sided equality hypotheses, with an actual sample size $n_b = 72$, with $K = \frac{n_a}{n_b} = 1$

| Dimension | | Test Condition Mean(SD) | Collaborative Condition Mean(SD) | Power $1-\beta$ | Type I Error $\alpha$ | Required Sample Size |
|---|---|---|---|---|---|---|
| Studied Words | Nominal | 7.6(1.8) | 8.3(1.5) | 0.8 | 0.05 | 72 |
| | Individual | 7.5(1.8) | 8.3(1.5) | 0.8 | 0.05 | 56 |

This analysis showed that approximately 72 participants would be needed to achieve 80% power $(1 - \beta)$ at a 0.05 $\alpha$ level.

### 2.2. Procedures and Experimental Design

As shown in Figure 1, participants were randomly assigned to one of three experimental conditions, namely individual (DRM Single), nominal (DRM Nominal) and collaborative (DRM collaborative). The sample size enabled the experimental conditions to be balanced in terms of both gender of the participants and number of members in the groups (pair, triplet, quartet). Also, the members of every group were unknown to each other. Before starting the experiment, respondents were asked to fill out an anonymous questionnaire to collect socio-demographic and psychological data (Demographic and Psychological Assessment—DPA).

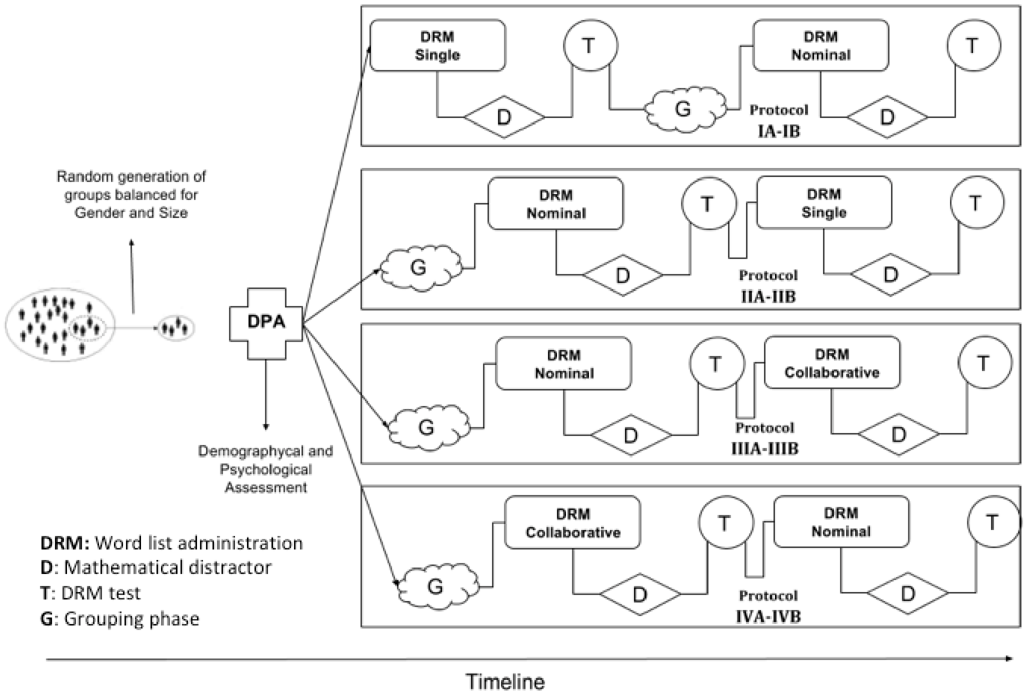


**Figure 1.** Experimental design. Note. In figure, the entire procedure for each protocol (i.e., Protocol IA-IB; Protocol IIA-IIB; Protocol IIIA-IIIB; Protocol IVA-IVB) is reported. Groups (i.e., subsamples) were balanced for all conditions (i.e., word list, order of experimental conditions, group size and gender composition).

In the individual condition (DRM Single), the participants performed the DRM test (T) alone and with the sole presence of the researcher. In this condition, all phases of the experiment took place in a small room of the Social Psychology Laboratory of the University of Florence. This room was equipped with a single laptop protected by the rigid structure. After the DPA, one participant was accompanied by a researcher to the small room while the other participants were waiting in a larger room of the laboratory along with a second researcher. During the DRM Single, the participant in the small room was told to remember a randomly assigned list of words (List A or List B—the two lists were balanced within each experiment). The list was presented by a video player for thirty seconds. During the mathematical distractor (D), the respondent was asked to complete a 3-min mathematical filler task to hinder rehearsal in short-term memory [58]. We used two mathematical fillers that were balanced across the experiment. Finally, during the DRM test (T), the subject was asked to recall the words of the displayed list by selecting words from a new list consisting of studied and non-studied words and as well as a critical lure [11].

Unlike the individual condition, the nominal and the collaborative condition took place in a large room of the laboratory. This room was prepared to provide from two to four laptops (according to the size of each participant group). Each laptop was protected by rigid structures that obstructed the view of the respective screens. Before the DRM Nominal and the DRM Collaborative, all participants were invited to interact with each other anonymously for 3 min within a VE (i.e., a chat line; grouping phase G). In order to focus on the VE, headphones playing white noise were used in order to avoid lacks of attention due to sounds coming from the real environment. As in the individual condition, both the nominal and the collaborative condition required that participants remember a randomly assigned list of words presented by a video player for thirty seconds and, then, they completed a mathematical distractor (D).

The DRM test (T) mode was what differentiated the nominal from the collaborative condition. In fact, in the nominal condition, each participant performed the DRM test (T) alone, in the largest room of the laboratory, with the presence of all the other members of the group. In the collaborative condition, instead, the group members had the possibility to carry out the DRM test (T) by cooperating with each other through the chat line. As regards to the collaboration, the instructions were not structured and no special rules were given on how to coordinate the recall, to manage speaking turns or tp solve disagreements (i.e., free-for-all collaboration).

The study was composed of four protocols (e.g., $I$; $II$; $III$; $IV$) divided into two sub-protocols ($IA, IB$; $IIA, IIB$; $IIIA, IIIB$; $IVA, IVB$):

1. Protocol $I$-$IA, IB$—individual/nominal;
2. Protocol $II$-$IIA, IIB$—nominal/individual;
3. Protocol $III$- $IIIA, IIIB$—nominal/collaborative;
4. Protocol $IV$-$IVA, IVB$—collaborative/nominal.

In every protocol, participants were 36 and they were tested in groups composed of pairs, triplets or quartets. Regardless of the protocols, the experiment consisted of two successive sessions. In the Protocol $I$-$IA, IB$—individual/nominal, the individual condition was applied in the first session and the nominal condition in the second session. On the contrary, in the Protocol $II$-$IIA, IIB$—nominal/individual, the nominal condition was applied first and then the individual condition. As regards to the Protocol $III$- $IIIA, IIIB$—nominal/collaborative, it foresaw first the nominal condition and second the collaborative one; vice versa for the last Protocol $IV$-$IVA, IVB$—collaborative/nominal. The letter A and B in the protocol wass used to indicate the word lists (List A or List B) which was administered first in the sub-protocol. For instance, in the Protocol $I$—individual/nominal, the sub-protocol $IA$ meant that List A was administered before (individual condition) and then List B (nominal condition). Conversely, in the sub-protocol $IB$ List B was administered first (individual condition) and then the List A (nominal condition). The order of the two lists was balanced within each protocol.

More specifically, as regards to the Protocol $I$-$IA, IB$—individual/nominal, in the first session (individual condition), each participant watched a first list in a video (DRM Single), did a first mathematical distraction (D) and then performed the DRM Test (T) alone while the other respondents of the pair, triple or quartet waited their turn in another room. In the second session (nominal condition), after the grouping phase (G) through the chat line, participants were invited to observe on their own laptop a second list, to do by themselves a second mathematical distraction and, then, to complete the DRM test (T) in the presence of the other participants but not interacting with each other.

Concerning the Protocol $II$-$IIA, IIB$—nominal/individual, the first and second session have been reversed.

In the Protocol $III$- $IIIA, IIIB$—nominal/collaborative, the first session (nominal condition) was the same as the Protocol $II$-$IIA, IIB$—nominal/individual. In the second session (collaborative condition), participants looked at a second word list (DRM Collaborative), did a second mathematical distractor (D) and recalled the words of the list (T) by collaborating with each other via the chat line.

As regards to the Protocol $IV$-$IVA, IVB$—collaborative/nominal, the two sessions have been inverted.

### *2.3. Experimental Setting: The Chat Line*

Even if the currently VEs devoted to support the Teleworking usually allow very advanced modality such as the video web conferences, the adoption of a chat based environments as experimental setting allowed to evaluate the social dynamics characterizing the groups under effectively controlled conditions. Of course it represents a very relevant dumping of interactivity potential, and as a consequence a sort of baseline for the evaluation of the impact of VEs on groups potential even in very constrained conditions.

The chat environment allowed the anonymity of the participants by means of a random assignment of a different avatar to each participant, thus excluding both the influence of the prior knowledge of the subjects, and those non verbal features affecting the dynamics and hard to be measured and quantified. In addition, such an approach standardized the available information of the group members at the beginning of any session, so making as measurable the pure effect of the web based interaction.

Of course a comprehensive approach to the modeling of "distance collaboration effectiveness" should consider the technological fluency and the computer literacy (i.e., VEs familiarity and self efficacy), but the usage of a web based chat room for a population of digital natives requires of course a natural skill for this population that can be assumed as usually already

The communication by the chat room was registered and computed to measure the communicative factors characterizing the group dynamics.

### *2.4. Measures*

#### 2.4.1. Psychological Measures

This study adopted the State-Trait Anxiety Inventory (X) to measure participant (state) level of anxiety before the experimental session [59]. The State Trait Anxiety Inventory is a brief and widely used self-report tool which measures the level of anxiety felt at the administration time.

The personality of the subjects was assessed by means of the 5-FasT test, whose scoring classifies the subjects by means of the five personality factors of the 'OCEAN' model [60].

#### 2.4.2. Task Measures

To achieve the main goal of assessing the occurrence of extra list words in a simple recall activity, four lists of words were used.

The first and second lists were, respectively, the Anger 15-Word List (List A) and the Music 15-Word List (List B) developed by Roediger and McDermott [11]. They were both translated into Italian. The List A consisted of abstract words concerning feelings, while the List B included concrete words such as musical instruments. According to the Dual Coding Theory (e.g., [14]), a list of abstract words appears to be more difficult to learn than a list of concrete words.

The third and fourth lists were both 20 words. More specifically, one word was the "critical lure" used in Roediger and McDermott's study [11], namely the word anger for the first list and the word music for the second list; 10 words were "real words" which had been randomly selected from the original Anger 15-Word List and Music 15-Word List; 9 words were "false words" which were new words (i.e., not present in the original 15-word lists). These "false words" were words associated with the original list in order to elicit the critical lures.

From the four lists, 5 dependent variables were obtained:

1. Non-studied words. It consists of the sum of false words and the critical lure indicated by the participant;
2. Studied words. It corresponds to the real words indicated by the participant;
3. True negative. It means the false words which the participant did not indicate;
4. False negative. It reflects the real words which the participant did not indicate;
5. Number of answers. It represents the total number of words indicated by the participant.

To obtain an average score of the group's performance, the score of each participant was summed with the score of the other group members.

### *2.5. Data Analysis*

As shown in Table 2, to evaluate the pre-conditions required for the subsequent inferential analysis, descriptive statistics have been calculated; the frequency distribution of the continuous variables, such as skewness and kurtosis $\in (-1; +1)$, has been verified; and the sufficient balance and size of the subsamples of interest has been checked (i.e., experimental condition, gender, and type of list).

As seen in Table 3, to evaluate the role of the experimental condition and the type of list (independent variables) on the subjects' performance (i.e., studied words and non-studied words as dependent variables), a MANCOVA analysis has been performed, entering the education variable as the covariate. We assumed such variable as a covariate since we proposed to control its effect on the performance. In fact, the Pearson correlation coefficient conducted on the performance revealed a negative relation with the non-studied words ($r = -0.247$, $p < 0.001$), which is confirmed by the F value in the MANCOVA analysis. To assess the association between group size, order of experimental conditions, personality and anxiety variables, gender effect and subjects' performance, Pearson's *r* correlation and Student's *t*-tests were conducted.

To test the relationship between the LIWC dimensions and the performance scores in terms of studied words and non-studied words within the collaborative condition, the linguistic content of the online chats was analyzed using the LIWC computer-program [50] and, then, the Pearson's *r* correlation has been carried out.

## 3. Results

Table 2 reports the descriptive statistics, skewness and kurtosis values, by gender and experimental conditions for the entire sample.

**Table 2.** Descriptive statistics of the subsamples. The variables reporting a skewness and kurtosis greater than 1 or smaller than −1 (*), have been normalized by means of a logarithmic transformation.

| Experimental Condition | Dimensions | Mean | S.D. | Skewness | Kurtosis |
|---|---|---|---|---|---|
| Collaborative condition—Males | Non-studied words | 2.42 | 1.90 | 0.93 | -0.10 |
| | Studied words | 8.22 | 1.76 | −0.67 | −0.83 |
| | False negatives | 1.78 | 1.76 | 0.67 | −0.83 |
| | True negatives | 7.58 | 1.90 | −0.93 | −0.10 |
| | Number of answers | 10.64 | 2.90 | −0.63 | 2.28 |
| Collaborative condition—Females | Non-studied words | 2.03 | 1.64 | 0.97 | 1.01 |
| | Studied words * | 8,36 | 1.38 | −0.49 | −0.59 |
| | False negatives * | 1.64 | 1.38 | 0.49 | −0.59 |
| | True negatives | 7.97 | 1.78 | −0.97 | 1.01 |
| | Number of answers | 10.39 | 1.91 | 0.51 | 0.55 |
| Nominal condition—Males | Non-studied words | 2.23 | 1.84 | 0.54 | −0.66 |
| | Studied words | 7.23 | 2.18 | −0.90 | 0.81 |
| | False negatives | 2.77 | 2.18 | 0.90 | 0.81 |
| | True negatives * | 7.77 | 1.84 | −0.54 | −0.66 |
| | Number of answers | 9.46 | 2.96 | 0.50 | 0.03 |
| Nominal condition—Females | Non-studied words | 2.22 | 2.00 | 0.56 | −0.97 |
| | Studied words | 7.97 | 1.63 | −0.25 | −1.23 |
| | False negatives | 2.03 | 1.63 | 0.25 | −1.23 |
| | True negatives | 7.78 | 2.00 | −0.56 | -0.97 |
| | Number of answers | 10.18 | 3.07 | 0.45 | −1.02 |
| Individual condition—Males | Non-studied words | 2.17 | 1.38 | 0.85 | 0.90 |
| | Studied words | 7.44 | 1.93 | −0.47 | 0.13 |
| | False negatives | 2.56 | 1.93 | 0.47 | 0.13 |
| | True negatives | 7.83 | 1.38 | −0.85 | 0.90 |
| | Number of answers | 9.61 | 2.45 | 0.54 | 1.46 |
| Individual condition—Females | Non-studied words | 2.22 | 1.94 | 0.48 | −0.98 |
| | Studied words | 7.67 | 1.79 | −0.38 | −0.88 |
| | False negatives | 2.33 | 1.79 | 0.38 | −0.88 |
| | True negatives | 7.78 | 1.94 | −0.48 | −0.98 |
| | Number of answers | 9.89 | 2.94 | 0.49 | −0.82 |

### 3.1. Effect of Experimental Conditions and Type of Word List on Subjects' Performance

In order to examine the influence of the experimental conditions (individual, nominal and collaborative condition) and the type of word list (abstract word list—the List A versus concrete word list—the List B) on the subjects' performance, a MANCOVA was carried out. As displayed in Table 3, the general model was significant on the dependent variables, showing an effect of the experimental condition for the studied words, an effect of the type of list for the non-studied words, and an interaction effect (experimental condition * type of list) for non-studied words.

With regard to the experimental condition affecting the studied words, we found a statistical difference between the collaborative condition and the other modalities (nominal and individual condition). These latter modalities were not significantly different between them. The performance of the collaborative condition appeared to be the highest, showing a greater number of studied words than the other conditions (Collaborative: $M = 8.29$; Nominal: $M = 7.61$; Individual: $M = 7.56$). Concerning the non-studied words, individual, nominal and collaborative conditions showed no difference between them, revealing the same average number of errors (Nominal: $M = 2.22$; Individual: $M = 2.19$; Collaborative: $M = 2.22$).

Regarding the type of list, results showed that the list referring to abstract words (feelings—List A: $M = 2.60$) elicited significantly more non-studied words than the list concerning concrete words (musical instruments—the List B: $M = 1.83$), revealing a greater difficulty. It is interesting to note that List A ($M = 7.57$) showed a non-significant trend in the collection of fewer studied words than List B ($M = 8.07$).

The interaction effect (experimental condition * type of list) emphasizes these results. The difference in difficulty between the List A (feelings) and the List B (musical instruments) decreases when the effect is matched with the experimental condition. Particularly, the experimental condition mitigates the effect of the list type on the non-studied words. The difference in difficulty between the two lists decreases from collaborative condition (List A: $M = 2.99$; List B: $M = 1.69$) to individual condition (List A: $M = 2.54$; List B: $M = 1.60$) and to nominal condition (List A: $M = 2.25$; List B: $M = 2.21$). Therefore, we may assume that the difficulty of the list is affected by the experimental condition, and mainly a greater effect of the difficulty of the List A (feelings) is revealed in the collaborative condition.

**Table 3.** MANCOVA on the subjects' performance. The letters "C", "N", "I" mean, respectively, the collaborative, nominal and individual experimental conditions. The letters "A" and "B" refer to the type of list, respectively the list of abstract words (feelings) and the list of concrete words (musical instruments). The model explains the 16% of the variance ($r^2 = 0.159$). * indicates the combined effects.

| **Effect** | **Wilks' Lambda** | **F** | **Sig.** | **$\eta^2$** |
|---|---|---|---|---|
| Education | 0.92 | 9.37 | $p < 0.001$ | 0.083 |
| Experimental condition | 0.95 | 4.41 | $p < 0.05$ | 0.021 |
| Type of list | 0.91 | 10.60 | $p < 0.001$ | 0.093 |
| Exp. cond. * List | 0.95 | 2.67 | $p < 0.05$ | 0.025 |
| Source | Dependent V. | F | Sig. | |
| Education | Non-studied words | 18.80 | $p < 0.001$ | |
| Experimental condition | Studied words (C > N/I) | 4.12 | $p < 0.05$ | |
| Type of list | Non-studied words (A > B) | 14.06 | $p < 0.001$ | |
| Exp. cond. * List | Non-studied words | 2.59 | $p < 0.05$ | |

### 3.2. Group Size and Order of the Experimental Condition

With respect to the subjects' performance and the experimental condition, the effect of the number of members in the group (group size) was investigated. Results show that this variable had no effect on subjects' performance, regardless of experimental conditions.

Instead, a Student's *t*-test revealed an effect regarding the experimental conditions order. Particularly, the collaborative condition showed a better performance when the nominal condition came first. In fact, the number of studied words was significantly greater when the collaborative condition was subsequent ($t = -2.5$, $p < 0.05$; $M = 7.64$ vs. $M = 8.44$), while false negatives were significantly lower ($t = 2.5$, $p < 0.05$; $M = 2.36$ vs. $M = 1.56$). On the other hand, any other experimental condition was found to be significant.

### *3.3. Personality Traits and State Anxiety*

The relation between the STAI and the 5-FasT scores and the subjects' performance was explored through Pearson's *r* correlation, with respect to the experimental condition and the gender of participants. Results showed a significant effect between anxiety and performance, while some interesting data were revealed for the 5-FasT scale. In the collaborative condition, closeness and conscientiousness factors were significantly and negatively related with the total number of answers ($r = -0.332$, $p < 0.05$; $r = -0.328$, $p < 0.05$), the number of studied words ($r = -0.325$, $p < 0.05$; $r = -0.356$, $p < 0.05$) and positively related with the number of non-studied words ($r = 0.325$, $p < 0.05$; $r = 0.356$, $p < 0.05$). Instead, a significant association was found for both the nominal and individual conditions.

Regarding the effect of the STAI on scores of female and male participants of the total sample, an association was found. As the 5-FasT scale, in the collaborative condition, females showed a negative relation between the conscientiousness factor and the total number of answers ($r = -0.461$, $p < 0.05$), the number of studied words ($r = -0.701$, $p < 0.01$) and a positive relation with the number of false negatives ($r = 0.701$, $p < 0.01$). On the other hand, male participants showed associations in all the experimental conditions. Regarding the collaborative condition, a relation was found between closeness factor and the number of studied words ($r = -0.449$, $p < 0.05$) and false negatives ($r = 0.449$, $p < 0.05$), while in the nominal condition, the agreeableness factor was related to the number of non-studied words ($r = -0.378$, $p < 0.05$) and the true negatives ($r = 0.378$, $p < 0.05$). In the end, males showed a significant association between the surgency factor and the total number of answers ($r = -0.511$, $p < 0.05$), the non-studied words ($r = 0.697$, $p < 0.01$) and the true negatives ($r = -0.697$, $p < 0.01$).

### *3.4. Gender Effect*

We conducted Student's *t*-tests to examine the gender differences in the subjects' performance in terms of studied words, non-studied words and the total number of answers, and to detect the influence of the group composition characteristics (same-gender, gender majority, and mixed-gender groups).

Results are shown in Table 4. Females compared to males showed a better performance characterized by a greater number of studied words both in the total sample and in the nominal condition.

As regards to the same-gender groups, homogeneous female groups exhibited better performance in all experimental conditions, since they reported a smaller number of non-studied words in the collaborative condition, and a greater number of studied words in both individual and nominal conditions, as well as in the total sample.

Concerning the gender majority groups, the prevalent female groups similarly show a significantly greater number of studied words in both individual and nominal conditions, while a difference was observed with respect to the collaborative condition.

**Table 4.** Gender effect. The table shows the characteristics of the group composition in terms of gender and their effect on the subjects' performance. A positive t value means that the group mentioned first in the table has, compared to the second group, a significantly higher average and vice versa.

| Group | Variable | t value | Sig. |
|---|---|---|---|
| Males | Studied words Tot Sample | −1.971 | $p < 0.05$ |
| vs. | Individual condition | - | ns |
| Females | Studied words Nominal condition | −2.104 | $p < 0.05$ |
| | Collaborative condition | - | ns |
| Homogeneous male groups | Studied words Tot Sample | −2.496 | $p < 0.01$ |
| vs. | Studied words Individual condition | −2.053 | $p < 0.05$ |
| Homogeneous female groups | Studied words Nominal condition | −2.164 | $p < 0.05$ |
| | Non-studied words Collaborative condition | 1.983 | $p < 0.05$ |
| Prevalent male groups | Studied words Tot Sample | −2.759 | $p < 0.01$ |
| vs. | Studied words Individual condition | −2.634 | $p < 0.01$ |
| Prevalent female groups | Studied words Nominal condition | −2.413 | $p < 0.05$ |
| | Collaborative condition | - | ns |
| Homogeneous groups | Total responses Tot Sample | 2.096 | $p < 0.05$ |
| vs. | Individual condition | - | ns |
| Heterogeneous groups | Non-studied words Nominal condition | 2.008 | $p < 0.05$ |
| | Studied words Collaborative condition | 2.946 | $p < 0.001$ |
| | Total responses Collaborative condition | 2.389 | $p < 0.05$ |

Finally, as regards to the mixed-gender groups, the results highlight that homogeneous groups, compared to heterogeneous groups, showed more studied words and total responses in the collaborative condition. They also reported a higher number of responses (i.e., total responses) in the total sample. In contrast, heterogeneous groups showed a smaller number of non-studied words in the nominal condition.

### *3.5. Social Interactions Analysis*

To examine the relationship between participants' involvement in the chat line and performance in the DRM task, we analyzed the social interactions that took place in the chat line among members of the collaborative condition groups through Pearson's *r* correlations between the subjects' performance and all LIWC categories [50]. Results are shown in Table 5.

Increased participation in the chat line by group members (LIWC category—Word Count) and addressing a chat message to all members of the group (LIWC categories—2nd Pers. Plur.; Other people), rather than just one member (LIWC category—2nd Pers. Sing.) seem to lead to a higher number of studied words within the virtual collaborative groups. However, the using of second-person plural is also related to a higher number of non-studied words. Lastly, communication marked by certainty and the utilization of negations seems to elicit fewer non-studied words. On the contrary, communication characterized by swear words and a distinct consensus within the group seems to be correlated with a smaller number of average studied words.

**Table 5.** Pearson's *r* correlations between Linguistic Inquiry Word Count (LIWC) categories and subjects' performance. With regard to the subjects' performance, the studied words and non-studied words mean the total performance of the group, whilst the average values of the studied words and non-studied words represent the total performance divided by the group size.

| LIWC Categories | Performance's Scores | Pearson's *r* | Sig. |
|---|---|---|---|
| Word Count | Studied words | 0.48 | $p < 0.01$ |
| 2nd Pers. Sing. | Studied words | −0.33 | $p < 0.05$ |
| Negations | Non-studied words | −0.28 | $p < 0.05$ |
| | Average Non-studied words | −0.33 | $p < 0.05$ |
| Assent | Average Studied words | −0.35 | $p < 0.01$ |
| Certainty | Non-studied words | −0.30 | $p < 0.05$ |
| | Average Non-studied words | −0.30 | $p < 0.05$ |
| Other People | Studied words | 0.34 | $p < 0.05$ |
| Swear words | Average Studied words | −0.41 | $p < 0.01$ |
| 2nd Pers. Plur. | Non-studied words | 0.52 | $p < 0.01$ |
| | Studied words | 0.61 | $p < 0.01$ |

## 4. Discussion

Our main result appears to be the presence of the collaborative facilitation and the disappearance of the collaborative inhibition in the VE. Indeed, collaborative groups obtain the best performance, with a greater number of studied words, thus suggesting an effect of collaborative facilitation. On the contrary, the number of non-studied words appears to be similar for all conditions, underlining that an effect of the false recall is absent (Table 2). These result are in accordance with the literature (e.g., [8]), while they contrast other studies (e.g., [12,13]) about an effect of collaborative inhibition. Then, it appears that our study reveals peculiar characteristics of the collaborative dynamics of small groups in VEs when members are engaged in a task about the DRM paradigm. The difficulty difference between lists mainly emerged in the collaborative condition. For this reason, the low number of non-studied words in the collaborative condition for the concrete list (list B) may point out that the collaborative facilitation could interact with the performance in simpler tasks. On the contrary, a significantly higher number of non-studied words collected by the collaborative condition in the abstract list (list A) may underline an inhibition of collaboration depending on a greater complexity of the task. These findings underline a new peculiarity of the social dynamics in VEs. Future research may investigate the relation between collaborative facilitation, collaborative inhibition and complexity/difficulty of the task. However, results regarding the difficulty of the lists have confirmed literature and our hypotheses. Indeed, concrete concepts appear easier to recall than abstract words, since concrete words can give a mental image, and facilitate the identification of the critical lures [14].

On the other hand, another interesting result of this work is about the nominal group. In particular, when the effect of both list and experimental conditions are matched, the nominal groups show very similar performance on both lists, revealing not to betray a greater difficulty of the list A. Moreover, when such condition precedes the collaborative condition, the latter reveals a greater performance. Such a result contrasts literature, since it was only revealed that prior collaboration enhanced subsequent individual recall with DRM paradigm, while a beneficial effect of the nominal condition on the collaborative was not observed yet [7,17]. These results seem to highlight the hypothesis that some specific social scripts may be started in groups in a VE, and this can be true even when participants are in a non-interactive (i.e., nominal groups) condition. Social mechanisms have been hypothesized to facilitate or inhibit the group performance [9]. Since in the nominal condition participants were in the same room, our results suggest that the presence of others may activate some social processes able to improve the subjects' performance [37]. Instead, for the same mechanism, when nominal condition starts after collaborative condition, it is possible that the motivation decreases. Again, it appears that the VE may play a role in mediating such dynamics, and future studies should focus on this perspective.

By contrast, the group size had no effect on the group performance, which appears not to confirm specific literature about the DRM paradigm [17]. However, our study involved groups with only two, three or four members each, and future studies could investigate if a higher number of members in the group may produce some effect in the performance.

With regard to the personality and anxiety effect on the group performance, anxiety did not reveal any relation, while literature affirmed that lower levels of anxiety may increase learning processes in online settings [21,25,26]. Perhaps, specific features of the tasks we applied may not be affected by individual state anxiety. On the contrary, lower scores of closeness and conscientiousness appear to increase the number of answers and studied words, and to decrease the number of non-studied words in the collaborative condition. Since a previous study showed that people with a lower score of conscientiousness appeared to prefer online training than FtF teaching [24], our results seem to partially confirm the literature, as less conscientious people show a better and more satisfying performance. Also, this study investigated possible gender differences in the relation between personality and performance. It was revealed that less conscientious females provided a higher number of answers, studied words and a lower number of false negatives in the collaborative condition. Hence, it appears that such personality feature may have a role in the group performance when females are in interactive circumstances, as in the collaborative condition. On the other hand, lower closeness, higher agreeableness, and lower surgency appear to enhance the males' performances in the collaborative, nominal and individual condition, respectively. Then, personality features affect the males' performance in all the experimental conditions, maybe revealing a wider role than in females' performance.

Concerning gender effect, females perform better than males, both in the total sample and, particularly, in the nominal condition, by achieving a higher number of studied words. Also, female groups show a lower number of non-studied words in the collaborative condition, and a higher number of studied words in the total sample, individual condition, and nominal condition. Moreover, predominant female groups show a better performance than predominant male groups, since they display a higher number of studied words in the total sample, individual condition, and nominal condition. These results confirm literature that female groups [32] and predominant female groups [31] are suitable grouping for CSCL. Interestingly, a difference was found in the collaborative condition, highlighting the positive effect of collaboration in leveling best and worst performances, improving the latter [61]. Regarding the mixed-gender groups, they obtain a lower number of studied words in the collaborative condition. These results confirm literature about a better performance of the same-gender groups, perhaps because of a higher focus on the task [28]. Nevertheless, mixed-gender groups exhibit a lower number of non-studied words in the nominal condition. Perhaps the females' performance enhances the males' performance in this condition, thanks to females' individual performances that improve the results of the mixed-group [62]. Hence, a gender effect is also observed in VEs, and it is comparable to the effect in real environments.

Finally, the analysis of the transcriptions of the online chat line in the collaborative condition displays that a greater participation is related to a better performance of the group. These results confirm literature [49]. It might be hypothesized that the more the messages are sent, the more the group share knowledge and, consequently, realize a better performance in decision-making tasks. Since Joinson and Paine [52] affirmed that a higher number of words in a virtual interaction reveals the presence of self-disclosed people, such aspect might imply a self-disclosure attitude increasing the group performance. Moreover, the use of negations between members is related to a fewer number of non-studied words, confirming literature which claims a higher cognitive complexity in such people [53]. In addition, our results underline that communication directed to all members of the virtual group (instead of just one member) appear to increase the group's performance. As Chung and Pennebaker [53] highlighted that the use of third person pronouns is related to enhance a focus on other people and to increase an in-group perception, our results may underline that to refer to other people may elicit the same goal.

In the end, collaborative groups revealed the best performance, confirming another study where interactions among members is a strong predictor for successful performances in VEs [48]. Hence, virtual social interactions are essential to better understand CSCL [45], and they appear to affect the effectiveness of collaborative learning process [46,47]. The main results of our study, combined with the virtual interactions content analysis, may suggest useful information concerning collective reasoning and e-learning dynamics, which are crucial and current themes in the field of educational communities, organizations and web communities at large.

## 5. Conclusions

During the writing of the present paper, the still ongoing COVID-19 worldwide emergency definitely promoted a wide adoption of teleworking modalities for many people around the world [3], to face with the brand-new societal organization of the world required by the pandemic. Within this scenario, a large percentage of organizations have been forced to partially re-design the internal procedures, so making more relevant than before to understand the real impact of VEs on the teamwork dynamics [4,5].

In particular, investigations about how teamwork design would shape the impact of team virtuality on team functioning, and what work design variables would influence team functioning and effectiveness [63], require to take into consideration both the fundamentals of team performance, as well as those intermediary cognitive processes and outcomes (i.e., team cognitive dynamics and cognitive performance), under conditions of high and low virtuality.

Collaborative learning and collaborative inhibition are two cognitive processes commonly required by many group tasks, and of course, can be considered as a sort of cognitive building blocks of many teamwork activities [7,9,38,39]. Despite such cognitive dynamics would appear as so relevant for several settings, so far it is not well-defined whether such processes are affected positively or negatively by VEs. In this study, we decided to take into account the cognitive process of recall, in order to have a quite robust, and low level, observable to compare individuals and groups cognitive performances. The present research found peculiar features of collaborative small group dynamics in VEs, and most importantly the disappearance (or mitigation) of collaborative inhibition in these settings. Moreover, when the effect of both task difficulty and group condition is matched, the nominal groups show very similar performance regardless of the difficulty of the problem. Furthermore, when such a condition comes before the collaborative condition, the latter yields better performance. These two results underline how the VE could be designed to enhance the effect of the group nominal condition, as well as of group collaborative condition, regardless of the difficulty of the problem.

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