Effects of implied social presence and interaction on attention in a virtual setting

by

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Abstract

The social interactions that we engage in with those around us are crucial to our successful navigation of daily life, and the presence of others can largely influence our attentional allocation. However, less is known regarding social presence and interactions as they occur online; as the recent pandemic has led to a shift to online virtual social gatherings, it is even more imperative for us to understand the ways in which this can affect our attention. Here, we sought to understand whether implied social interaction and implied social presence can affect attention in a *virtual* visual search task. Implied social interaction was operationalized by telling participants they were cooperating and competing with a partner, while implied social presence was operationalized by the visual depiction of the other player on screen. To solidify our manipulation of implied social interaction, feedback was provided in the form of telling participants whether they were accurate or not, and their relative speed compared to the previous pair (cooperation) or compared to the opponent (competition). Our results indicate that, in line with prior work, participants who were told they were competing were significantly faster but less accurate than those who were told they were cooperating, suggesting that it is feasible to study implied social interactions using a virtual format. Although we did not find a significant interaction between this effect and our social presence manipulation, when comparing social presence to a baseline condition with no partner evoked, we found that participants prioritized accuracy when told they were cooperating and speed when told they were competing as compared to individual search. These findings suggest that the threshold to imply social presence may be lower than we thought, and that our cognitions regarding our social interactions can play a large role in affecting our attention.

Keywords: visual search, attention, cooperation, competition, implied social presence

Preface

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Introduction

Human attention is not a solitary concept, but exists within a framework of other mental processes and can be largely affected by the environment (Puce & Bertenthal, 2015). Indeed, there are a myriad of ways that social context can modulate our behaviour such that the presence of those around us plays a crucial role in the way that we allocate our attentional resources (e.g., Gallup, Chong, et al., 2012; Laidlaw et al., 2011; Latane & Zipf, 1981). Early research has demonstrated that the mere presence of another individual can influence diverse overt behaviours such as the amount of time we devote to sorting through material with erotic visuals (Weiss et al., 1971), our performance on cognitive tasks (Dashiell, 1930), and our likelihood of conforming to a social norm (Guerin, 1986).

Turning specifically to attention, researchers have begun to investigate the role of social presence on attention, and have found that the presence of others can also affect the ways that we allocate our attention (Gallup, Hale, et al., 2012; Laidlaw et al., 2011; Macdonald & Tatler, 2018; Risko & Kingstone, 2011). However, this work has largely focused on the effect of a physically-present individual on attention, with less known regarding whether *implied* social presence, in which the presence of another individual is implied by the experimental instructions or setup, can also elicit changes in attention. Further, there have been few experiments researching the effects of *virtual* implied social presence on attention, especially when an interaction is explicitly suggested (e.g. deceiving participants) by the experimenters. Due to the recent global pandemic, in which restrictions have been placed on our amount of in-person social interaction, it is imperative to understand the potential effects of various levels of social presence on our attention as we learn to navigate virtual interactions as a regular form of communication. To investigate attention as it varies among different levels of implied social presence, we used an online platform to administer a traditional visual search task to quantify attention. The use of an online platform facilitated our manipulation of social presence, as we had control over the degree to which our participant's implied partner was represented; from no visual depiction of the partner up to a short video-chat with a presumed participant (who was in fact a confederate) prior to performing the visual search task. Because previous work has shown that there is a collective benefit of dyadic search, such that two people are faster and more accurate when searching together as compared to alone, we wanted to see whether this same finding can be replicated under conditions in which the physical presence of another person is absent, while only the virtual implication remains (A. A. Brennan & Enns, 2015; S. E. Brennan et al., 2008; Wahn et al., 2017). Additionally, we manipulated social interaction by asking participants to both cooperate and compete with their "partner" to see whether they were faster and less accurate when competing as compared to cooperating with an *implied* partner (Niehorster et al., 2019). As such, we investigated the ways that attention, indexed as speed and accuracy, in a virtual cooperative and competitive visual search task differed across different levels of implied social presence. Our aim was to determine whether *implied* social presence and *implied* social interaction can elicit changes in attention even via an online format.

Ways of Measuring Attention

When investigating spatial attention, researchers have typically focused on two types of behavioural observations; namely, chronometric measures such as manual button presses for target events, or looking behaviours towards target and non-target events (e.g., Hayward et al., 2017; Posner, 1980). The former is a measure of covert attention, whereby attention is not presumed to be coupled to eye gaze (Driver et al., 1999; Posner, 1980), and the latter is a measure of overt attention, whereby attention is inferred from gaze behaviour (Birmingham et al., 2008; Gallup, Chong, et al., 2012; Hayward et al., 2017). It is thus feasible to assess social attention in various ways. For example, one method used to assess covert attention is the Posner cueing paradigm, in which participants are asked to fixate at the centre of the screen and allow their attention to wander; targets then appear in the periphery a variable amount of time after the presentation of a directional cue (e.g. arrow, averted eyes, etc.) that is either predictive or non-predictive of the target's location (Posner, 1980), and results from the cueing procedure are robust. For example, the typical response for a central non-predictive gaze cue shows that participants are faster to respond to targets at cued as compared to uncued locations, even when asked to ignore the central cue (Driver et al., 1999; Frischen et al., 2007; Hayward & Ristic, 2015), suggesting that attention to gaze is prioritized. Another common method researchers use to study covert attention is by presenting participants with a number of stimuli, but asking them to only attend to one. Participants can be asked to fixate at the centre of the screen while allowing their attention to wander, and the dependent variables include reaction time and accuracy measures from manual button presses. For example, in a visual search task, participants are presented with an array of objects on screen and asked to press one key when a target is present, and another when the target is absent (Horstmann et al., 2016; Levin et al., 2001). In these tasks, researchers have determined that participants tend to be faster when the target is present as compared to absent, and in cases where the target has more than one defining feature, that participants are faster when fewer items are on screen (Treisman & Gelade, 1980; Wolfe, 1994).

Overt attention, in turn, is measuring eye movement behaviours as an index of attention. For instance, overt attention can be operationalized as the proportion of time that participants spend looking at specific stimuli, the first item looked at (i.e., first fixation), or the pattern of gaze movements between various stimuli on-screen (i.e., saccades). Attention is thus inferred to be coupled to eye gaze in these instances, and typical findings show that we tend to preferentially look at eyes and social cues, both in the laboratory and while conversing in the real world (Birmingham et al., 2008; Hayward et al., 2017), that we tend to initially fixate on the centre of a scene when viewing images on a computer screen (Tatler, 2007), and that our saccade patterns for scenes are largely dependent on cultural factors and previously examined locations (Chua et al., 2005; R. M. Klein & MacInnes, 1999). Applying overt gaze measures to implied social presence, prior work demonstrates that the implied social presence of an eye-tracker can lead to participants changing their looking behaviour in a more prosocial manner (Nasiopoulos et al., 2015). One way researchers investigated people's saccade patterns when paying attention on screen was by presenting visual scenes from the "Where's Waldo" books; they determined that participants tend to avoid looking at previously-examined locations when searching for a target (R. M. Klein & MacInnes, 1999), suggesting that we try to optimize our search strategies by inhibiting the locations we just searched.

Although eye-tracking measures are beneficial for studying attention in the real world in which we cannot incorporate manual button presses, human attention is not always coupled to eye gaze (Posner, 1980). As such, our use of chronometric measures to study attention is not only more suitable for our online platform as the low resolution of webcam-based trackers renders overt measures of attention less reliable, but is also supported by countless previous experiments and is believed to be a pure measure of attention (Foulsham et al., 2014; MacInnes et al., 2014). In sum, there are various methods that researchers use to measure social attention, including reaction time and accuracy in the lab to measure performance, and gaze behaviour in the lab as well as the real world to infer locus of attention, with the choice of method depending on the context and research question.

Implied Social Presence on Attention

To date, there have been some investigations examining the effect of specifically *implied* social presence on one's attention. For example, one group of researchers used eye-tracking software as a way of implying social presence, by manipulating whether participants were told the eye-tracker was functional or not; those who were told the eye-tracker was functional were in the implied social presence group, while those who were told the eye-tracker was not functional were in the no implied social presence group (Risko & Kingstone, 2011). All participants were then placed in a room with a provocative swimsuit calendar (Risko & Kingstone, 2011). Results showed that significantly more participants looked at the calendar in the condition when social presence wasn't implied as compared to when it was implied, but that the same patterns did not emerge when a neutral calendar was used as the stimulus (Risko & Kingstone, 2011). As such, participants' overt attention changed as a result of a change in the level of implied social presence, specifically when there was a possibility that they may later be judged on their behaviour (Risko & Kingstone, 2011). A similar implied social presence manipulation was also adopted, where researchers asked participants to perform a visual search task under both videotaped and non-videotaped conditions (Miyazaki, 2015). Results showed that participants were significantly more accurate when they were told that their behaviour would be videotaped and later analyzed than when there was no video camera in the room (Miyazaki, 2015). In both of these studies, implied social presence was operationalized via the use of an eye-tracker or camera, making it a feature of the experimental setup as opposed to any explicit experimental instructions.

Another way researchers have investigated implied social presence is through controlling the likelihood that participants will run into another person during the completion of an embarrassing activity (Dahl et al., 2001). For instance, Dahl and colleagues (2001) asked participants to purchase condoms from a vending machine inside a bathroom; crucially, they were either told that the bathroom would be closed off for the study with signs and pylons placed outside (no implied social presence condition) or that the bathroom would be open to the public (implied social presence condition; Dahl et al., 2001). Results indicated that participants who were in the implied social presence condition reported higher ratings of embarrassment upon returning to the experimenter after the purchase, as well as reported higher levels of imagined social presence than participants in the no implied social presence condition (Dahl et al., 2001). Thus, the mere potential of encountering another person can lead to differences in how we feel about performing the same action.

There are therefore various ways to imply social presence, from the placement of a video camera in the testing room to implying to participants that there is the chance of encountering another person. While important, these studies do not typically test whether performance changes when participants are told in an explicit manner that they are interacting with another person, leaving it unclear whether this type of manipulation of social presence might affect attention. Because of this gap in the literature, we decided to manipulate implied social presence in an even more explicit fashion.

Two-Person (Dyadic) Tasks

Researchers have investigated the ways in which attention differs between dyadic search and individual search by manipulating the types of information given to participants, such as their partner's gaze behaviour or performance, and found that in general, two people are faster and more accurate when searching together as compared to alone, unless they are competing against each other (A. A. Brennan & Enns, 2015; Niehorster et al., 2019; Siirtola et al., 2019; Wahn et al., 2017). For instance, in a cooperative visual search task in which participants were provided with their partner's gaze behaviour on screen, results showed that participants were able to efficiently divide up the search space despite not being able to verbally communicate (Siirtola et al., 2019). Moreover, when researchers manipulated the amount of information that they provided participants performing cooperative search, they found that providing any piece of information (which target their partner chose, their partner's scores, or both) led to higher scores than individual search (Wahn et al., 2017). Thus, working cooperatively with another person changes the way that individuals search for targets, and the benefits of specifically in-person dyadic search have now been supported by many experiments (Juni & Eckstein, 2017; Voinov et al., 2019; Wahn et al., 2018). Turning to studying how attention differs between cooperation and competition between two physically-present individuals, researchers asked partners to search for a target on screen both cooperatively and competitively (Niehorster et al., 2019). Here, they found that participants were faster but less accurate when competing as compared to cooperating (Niehorster et al., 2019). This suggests that there is a speed-accuracy trade-off, such that participants either prioritized speed (when competing) *or* accuracy (when cooperating) (Niehorster et al., 2019). By extending the use of visual search tasks to study dyadic interactions, it becomes feasible to understand the differences in attention between individual and dyadic search. Importantly, as there is currently a dearth of information about competitive search, our results will also be able to inform the field's understanding of implied competition on behaviour.

Considerations for Online Testing

Visual search tasks have been widely used as a tool to study attentional phenomena and can easily be extended to study implied dyadic interactions. Although visual search tasks are generally administered face-to-face, the structure of the task lends itself nicely to online testing. Prior work examining the differences between online and in-person testing have found that despite a higher dropout rate for online experiments, there is no general difference in participants' level of performance, and that even long-lasting tasks that require sustained concentration are feasible to administer online (Dandurand et al., 2008; Gould et al., 2015). As such, we expect that the results of our experiment should be comparable to those obtained from in-person testing.

The Present Study

The present study aimed to investigate the ways in which implied social presence and implied social interaction in an online setting affect attention. To do so, we employed a visual search task in which participants were asked to determine whether a specific target was present or absent on-screen. We manipulated implied social presence through the use of visual depictions that increased in realism (between-subjects), and we told participants that they would be completing the task with another person. We manipulated implied social interaction through the use of blocks of trials where the participants were told they were either cooperating or competing to find the target. Further, to determine whether our narrative of playing with another individual truly implied a social presence to our participants, we included two baseline conditions in which we did not tell participants that they interacted with a partner. In one condition (points), participants performed an identical task save for the instruction of playing with another individual, and in the other condition (baseline), participants completed a visual search task solo with no points/feedback, in order to determine whether the mere act of receiving points can affect performance.

We hypothesized that, if virtual implied cooperation and competition can affect attention in the same way as real cooperation and competition between two physically-present individuals, then participants will perform the visual search task faster but less accurately when competing as compared to when cooperating (Niehorster et al., 2019), and when compared to our points group, the cooperation group will be faster and more accurate due to prior work demonstrating a collective benefit of dyadic search (A. A. Brennan & Enns, 2015; Wahn et al., 2017), while the competition group will be faster but less accurate (Niehorster et al., 2019). Finally, if the increase in realism of the visual depiction of the partner truly captures an increase in social presence, then we expect to see larger performance differences between cooperation and competition between those performing the visual search task under higher as opposed to lower levels of implied social presence.

Methods

Participants

281 University of Alberta students were recruited through the Undergraduate Research Participation Program and received course credit as compensation. After data processing and cleaning, final analyses were run on 188 students (142 females, 43 males, 2 non-binary, 1 prefer not to say; 171 right-handed, 17 left-handed; M_{age} = 19.64, SD_{age} = 2.57). Rationale for all participant removals is outlined below. All participants provided informed consent through overt action (i.e., checking the box indicating their consent to participate).

Apparatus and Stimuli

The virtual experiment was conducted on participants' personal computers over the internet employing the software Lab.js, which provides an online interface for creating behavioural and cognitive studies by allowing users to put texts and images on screen, along with components to structure the experimental design. The programming languages JavaScript and HTML were used to program the experiment, CSS was used for styling, and Python was used to reformat the data afterwards, and the study was hosted on the VASP lab's ComputeCanada server. While online testing is less common, prior work has tested the precision of stimulus timing via online platforms, and found the mean variability (the inter-trial standard deviations of the latencies) for reaction times and visual durations for various software, platform, and browser combinations (Bridges et al., 2020). Based on this information, we allowed participants to use platform and browser combinations (MacOS or Win10 computers using the browsers Chrome or Firefox; variance between 4.8-8.1ms; Bridges et al., 2020) that yielded relatively small values of variability, while also ensuring to provide some variability of combinations to ensure a broader participant pool. Thus, we only analyzed data from participants who completed the experiment using a MacBook or a Windows computer with either Chrome or Firefox internet browsers, resulting in the removal of 41 participants (see Appendix A for a table depicting timing variability and participant count for each operating system/browser combination, along with a histogram depicting the number of participants using each screen size).

Stimuli consisted of images obtained from the DinoLab Object Database (Hovhannisyan et al., 2021) and were supplemented with additional images chosen through a Google search, all of which were then cropped and grey-scaled using a Python script. The 60 distractor stimuli images were split equally into six categories present in the database, all of which were chosen to be relatively common objects: appliances, furniture, musical instruments, office supplies, tools, and vehicles (150 pixels x 150 pixels). The 10 target stimuli images consisted of five variations of books and mugs. The fixation display consisted of a black fixation cross (‘+’ with roughly 32 font size) presented in the centre of the screen against a white background, and the search display consisted of the fixation cross surrounded by six images placed at equal intervals along an imaginary oval (e.g. the distance between the central fixation cross and the horizontal items was 8 degrees of visual angle on a 13.3inch MacBook Air and 10 degrees on a 15.4inch MacBook Pro, and the distance between the cross and the diagonal items was 7.5 degrees of visual angle on a 13.3inch MacBook Air and 8 degrees on a 15.4inch MacBook Pro). The images used to represent the other participant (i.e., schematic, real, and confederate faces; 100 pixels x 100 pixels) were positioned in the top right corner of the search screen. The image of the schematic face was obtained through a Google search, the image of the real face was obtained from the Karolinska Database (ID: AF22HAS; Lundqvist et al., 1998), and the images of our confederates were taken as screenshots over a zoom meeting by our researcher, which were then cropped to have the same dimensions as the schematic and real faces (see Figure 1).

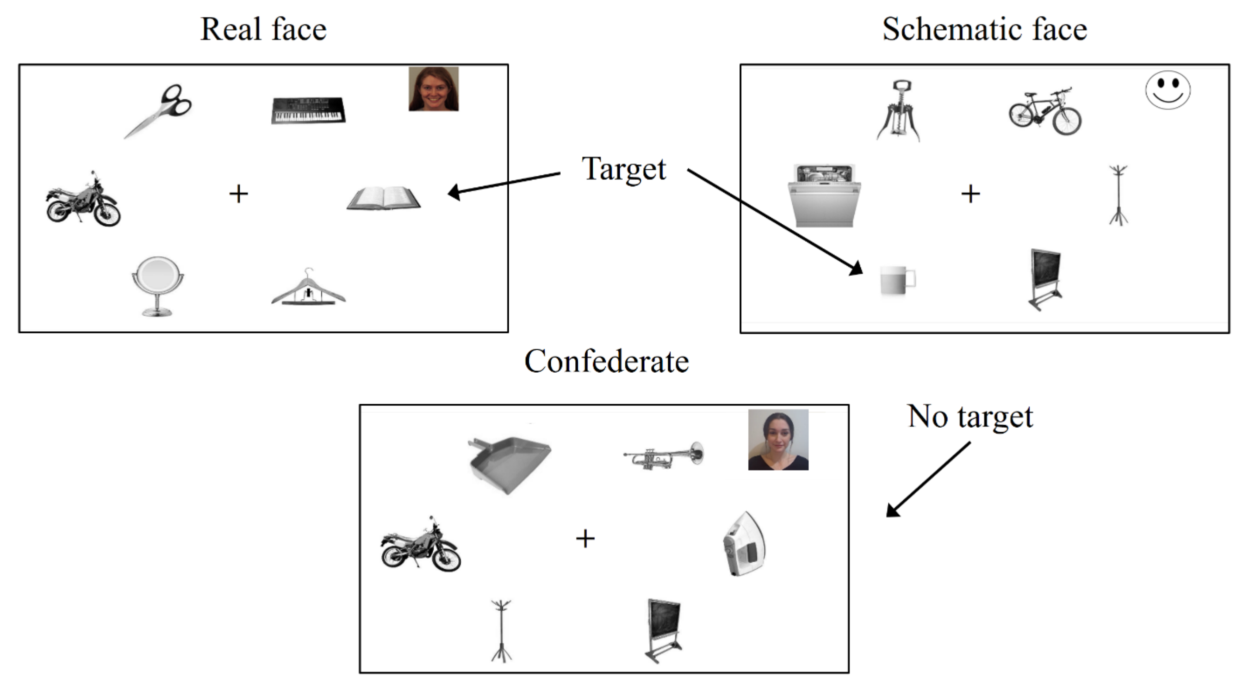

Figure 1. Example search displays are depicted, illustrating a trial from the real face condition (top left), the schematic face condition (top right), and the confederate condition (bottom). Target-present trials are seen in the top two examples, while a target-absent trial is shown in the bottom panel. Not to scale.

Design

The experiment consisted of a 2 x 4 mixed factorial design. The type of social interaction (e.g. mode: cooperation; competition) was a within-subjects factor, blocked and counterbalanced across participants, while implied social presence (visually absent; schematic face; real face; confederate) was a between-subjects factor. In addition, two additional baseline conditions were included in which participants were not told the narrative of playing with a partner at all (neither cooperation nor competition). Instead, participants in this group completed the experiment under both feedback (points) and no feedback (baseline) conditions with no image on-screen, in order to determine whether it is the mere act of receiving points that affects attention rather than our manipulations of implied social presence and social interaction. In line with previous visual search experiments, the dependent variables included reaction time (RT) and accuracy (Siirtola et al., 2019; Wolfe, 1994; Zhou et al., 2020).

Participants completed 21 practice trials before each condition (either cooperate and compete, or points and baseline), followed by 240 test trials per condition for a total of 480 test trials. Practice trials were identical to experimental trials, except that a new target image (alarm clock) was used and no feedback regarding awarded points was provided to the participants. All conditions received feedback regarding whether they correctly or incorrectly detected the target during practice trials. Trials were separated into three blocks of 80 trials, with 40 target-present and 40 target-absent trials. Target identity, target location, distractor identity, and distractor location were fully counterbalanced. Responses were followed by visual feedback indicating accuracy and number of points awarded in the cooperation, competition, and points blocks.

In order to determine a unique point system, we compared participants' RTs to an established RT threshold for each mode (cooperation and competition, or points and baseline). To do so, we calculated the average RT obtained from pilot-test data with volunteers (n=5 for cooperation/competition; n=6 for points/baseline), split by condition and target presence (Table 1).

Table 1: Average RT and accuracy (ACC) measures from pilot testing

		Target-present	**Target-absent**
Cooperation	mean RTs	792ms	969ms
	mean ACC	87.5%	95.8%
Competition	mean RTs	780ms	838ms
	mean ACC	86.8%	96.5%
Points	mean RTs	554ms	607ms
	mean ACC	88.0%	95.6%
Baseline	mean RTs	644ms	762ms
	mean ACC	93.8%	98%

At first glance, the threshold RTs for the points condition appear faster than those for the other conditions. To determine whether overall speeds were slower in cooperation and competition as compared to the points condition, we calculated the average RTs specifically for those participants who used their own thresholds (>96% of participants, RT range: 564-668ms), and found they were comparable to the average pilot RTs for the points and baseline conditions.

Participants were asked to repeat the practice trials (for a maximum of one additional time) if their accuracy fell below 50% for either target-present or target-absent trials, or if their average target-present *or* target-absent RTs were slower than the corresponding value from pilot testing. A threshold RT was then determined as either the participant's own average RTs for target-present and target-absent practice trials, or the pilot values in the case that participants' performance was still below 50% accuracy or too slow after two sets of practice trials. This threshold RT, determined after each set of practice trials, was then used as the comparison RT for the respective mode (see Appendix B for a table depicting the number of participants who used their own thresholds in each condition).

Based on accuracies determined from pilot testing the experiment (Table 1), we programmed the task such that the computer (or the "partner" playing with participants) would be inaccurate for six trials per block (7.5% of trials) in a random fashion. This was done to mimic a real partner's performance in each of our conditions (including points/baseline in order to maintain consistency between conditions).

In cooperation mode, participants were instructed that their RT would be averaged with their partner's RT to determine whether their average speed was faster or slower than the last pair of players. In this mode, points were allocated as follows (see Figure 2 for a graphical depiction): if the participant was incorrect, they were presented with a screen that read

“Incorrect! (+0pts)”. For trials where the computer was correct, if the participant was correct but slower than the RT threshold for that mode they were presented with the feedback “Too slow! (+5pts)”, while if they were correct and faster than the RT threshold they were presented with the feedback “Great job! (+10pts)”. However, if they were accurate but the computer was inaccurate, they were presented with the feedback “Other player incorrect! (+0pts)”; this was determined based on accuracy values obtained from pilot data (see Table 1) in order to mimic a real player’s performance and was programmed to occur for a maximum of 3 trials per block spaced at least 8 trials apart (to avoid errors all occurring too close in proximity to each other).

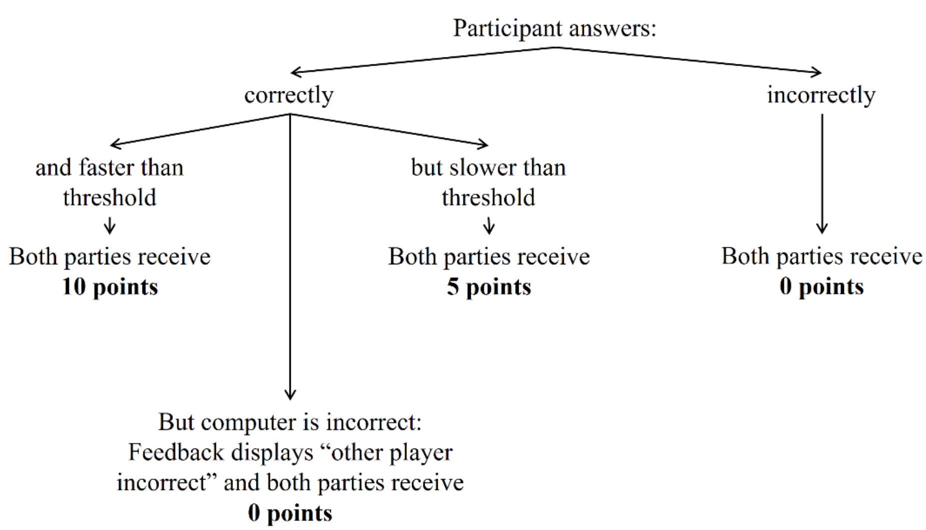

Figure 2. Flowchart displaying the allocation of points under different performance patterns for the cooperation mode.

In competition mode, participants were instructed that their performance would be compared to their partner’s performance. In this mode, if participants were inaccurate, they were presented with a feedback screen indicating “Incorrect! (+0pts)”. For trials where the computer was correct, if the participant was correct but slower than the RT threshold for this mode they were presented with the feedback "Too slow! (+5pts)" and if they were correct and faster than the RT threshold, they were presented with the feedback "Great job! (+10pts)". However, if they were accurate and slower than the RT threshold while the computer was inaccurate (which was programmed to occur for a maximum of 6 trials per block spaced at least 8 trials apart in order to mimic a real player's performance), they were presented with the feedback "Great job! (+10pts)". The computer's points were calculated based on the participant's performance such that, when both parties were accurate, the computer received 10 points when the participant received 5 and the computer received 5 points when the participant received 10. However, when the participant was inaccurate and received 0 points, the computer received 10 points if it was accurate, and received no points if it was inaccurate (Figure 3).

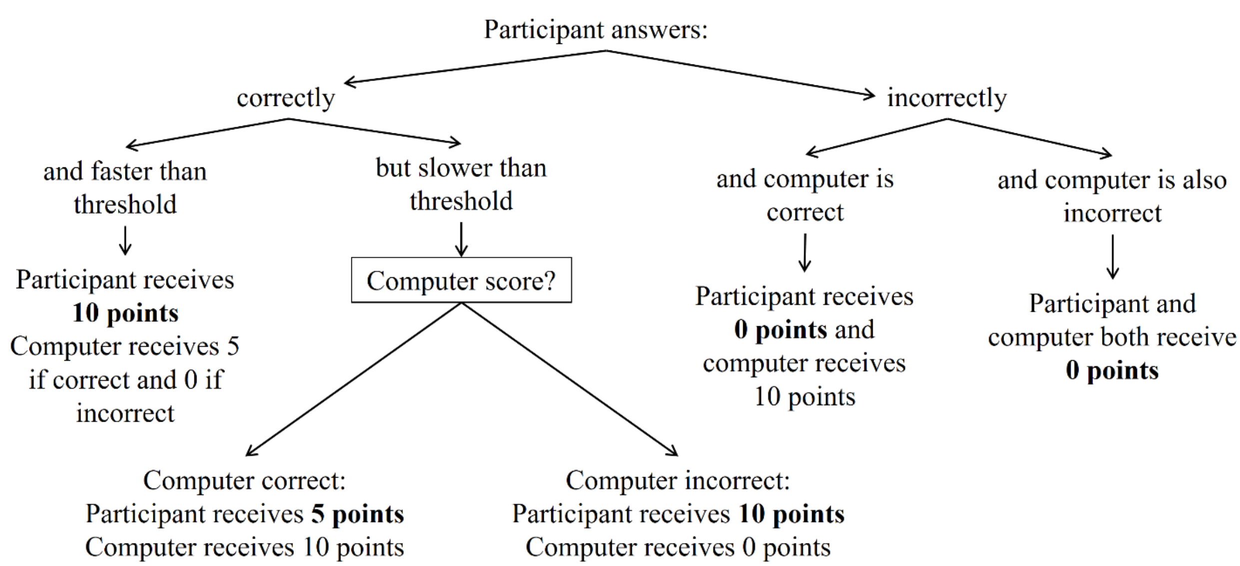

Figure 3. Flowchart displaying the allocation of points under different performance patterns for the competition mode.

In the points and baseline conditions, participants were not told they were competing or cooperating with anyone. In the points condition, when participants were faster than the threshold and accurate, they received the feedback "Great job! (+10pts)" and if they were slower than the threshold and accurate, they received the feedback “Too slow! (+5pts)”. However, if they answered inaccurately, they received the feedback “Incorrect! (+0pts)”. In the baseline condition, participants did not have a feedback screen, such that the trials continued from the search screen to the blank screen.

Procedure

Participants in the video condition specifically were provided with a scheduled zoom link, followed by task completion. Participants in all other conditions signed up for a scheduled testing time in order to perpetuate our cover story that they were working with a partner, and were provided with a link directing them to the computer task. In the four social presence conditions, participants were presented with written instructions on-screen indicating whether they were cooperating or competing with their partner in the first mode.

In the video condition, participants were provided with a link to a scheduled zoom meeting, and they began the experiment by interacting virtually with a researcher and a confederate, who posed as the other player. The researcher began by administering the consent form using Google Forms and by saying that the experiment involves studying how people compete and cooperate with one another. In order to control for familiarity, the researcher also confirmed that neither individual recognized the other. Participants were then told that in order to remind them that they are playing with a partner, we wanted to put a picture of their partner on their screen throughout the task, and we thus asked participants for consent to use their picture for the current experiment only. In actuality, no picture was taken, however to again bolster the belief that participants were indeed cooperating or competing with another individual, participants saw a picture of the confederate in the top right corner of the screen during the task.

Participants were allowed to participate without penalty regardless of whether they did or did not consent to the fictitious pictures. Of note, all participants consented to us taking their picture.

In the points and baseline conditions, participants were provided with a link at a specific time to an identical task, save for the instructions, as we did not include the statement telling participants that they were playing with a partner. No image was displayed on-screen, similar to the visually absent condition.

The sequence of events and time course for the experiment are shown in Figure 4. Each trial consisted of three displays: a fixation display, a search display, and a feedback display. Between each trial, there was an inter-trial interval blank screen for 650ms. The central fixation cross was displayed for 1500ms, after which a search array was displayed for 3000ms or until a key press was made. Finally, a feedback screen was displayed for 1000ms, indicating accuracy and number of points awarded (screen not present in the baseline mode).

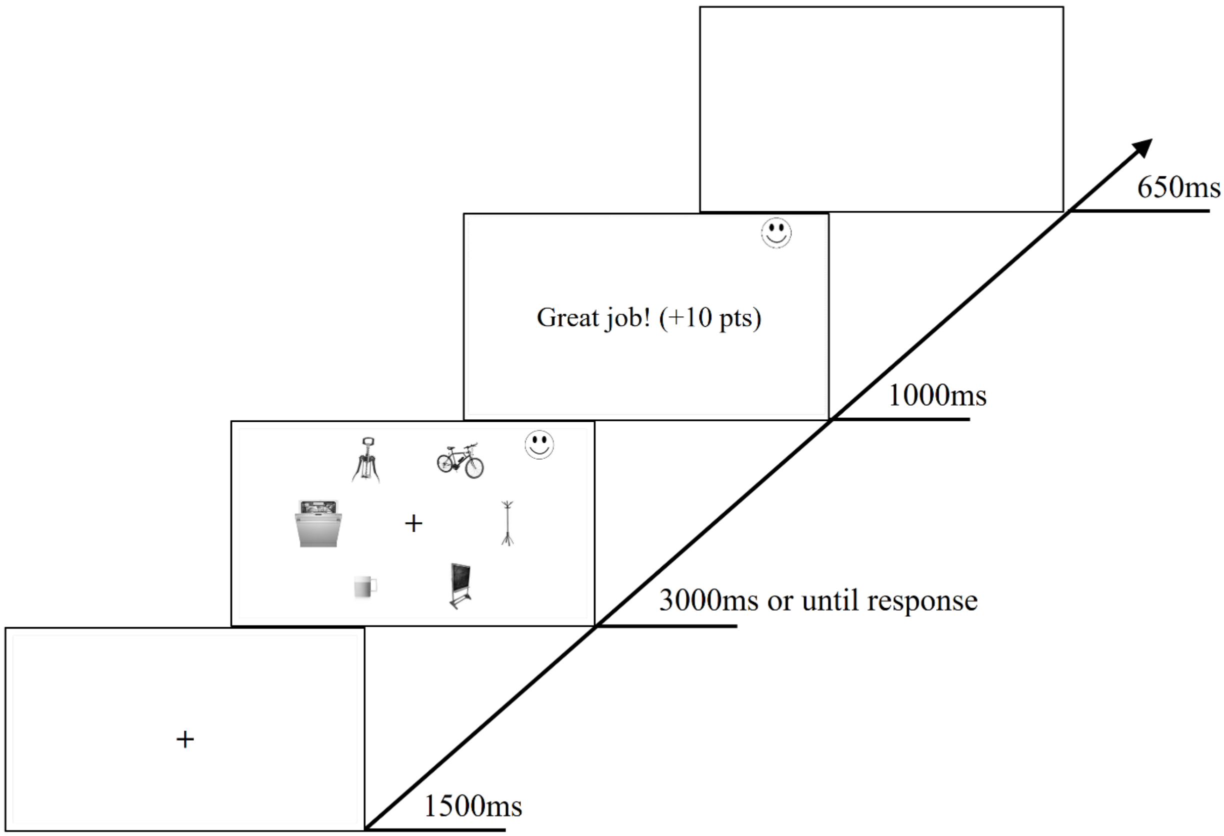

Figure 4. The trial sequence began with a central fixation cross for 1,500ms, after which a search array was displayed for 3,000ms or until key press. A feedback screen indicating accuracy and number of points awarded was then displayed for 1,000ms (screen not present for the baseline group), after which a blank screen was displayed for 650ms. The image defining the social presence condition was displayed in the top right corner of the search and feedback screens. Not to scale.

Participants were presented with written instructions at the beginning of the experiment telling them to position themselves 60cm or roughly an arm's length away from their screens, and were instructed before each mode to determine as quickly and as accurately as possible whether the target object (mug or book, counterbalanced across modes and participants) was present among the items on screen, and to press one key if the object was present and another if it was absent ('b' and 'h', counterbalanced across participants). For the conditions presenting points, participants' cumulative points were displayed after every block, with the points restarting from zero for each mode.

Once participants started the task, the experiment entered full-screen, the cursor disappeared, and participants were instructed to fixate on the central plus sign for the duration of the experiment. Participants also completed two questionnaires (the Competitive Orientation Measure to assess competitiveness and the Autism-Spectrum Quotient to assess autistic traits) after they completed the visual search task; however due to order effects found in our analyses causing half of our participants to not have competition data, we decided to not analyze any data from either of these questionnaires.

Results

Data Processing

All practice trials were excluded from analyses. We calculated anticipations (RTs<150ms) and timeouts (RTs>1500ms), and any participants who committed more than 10% timing errors were removed from analyses (n=27). In addition, any participant with low accuracy (less than 50% of target-present or target-absent trials within each mode; n=12) or who self-reported to not have normal or corrected-to-normal vision (n=6) were also removed from any analyses. Finally, those who had incomplete files (n=1), those who self-reported to have not tried on the task (rated as 1 out of 5 on the "How hard did you try?" question; n=6), and those who did not use the required operating system/browser combination (n=41) were also excluded from analyses (see Appendix C for a visual display of attrition and Table 2 for a breakdown of sample size across each condition; *Points* n=19; *Baseline* n=25). Of note, we found the same data patterns when analyzing data from all participants who met the RT and accuracy exclusion criteria, regardless of computer criteria.

Table 2. Depicts a breakdown of the number of participants per condition

	Cooperation	Competition
Visually absent	19	24
Schematic	17	19
Real	20	19
Confederate	12	14

Mean inter-participant RTs were calculated for accurate trials and were used in our analyses. For analyses with accuracy values, however, accuracy scores do not adhere to a normal distribution, in part due to their discrete nature that only spans a range from 0-1 (Dixon, 2008), however one assumption when running analysis of variance (ANOVAs) involves the data conforming to a normal distribution (Blanca Mena et al., 2017; Dixon, 2008). To mitigate these concerns, we applied arcsine transformation to participant accuracy scores which increases normality (Cohen & Cohen, 1983; Dixon, 2008). Reported analyses are based on these transformed accuracy scores. However, for ease of understanding, we have taken the mean arcsine values for each condition and transformed them back into percentages (i.e., sine transformed) for all subsequent graphical and numeric depictions (including tables).

First, we checked whether there were order effects between those who completed the cooperation versus competition conditions first, as order effects could undermine any interpretation of the data. This was achieved through running a repeated-measures analysis of variance (ANOVA) on inter-participant mean RTs with factors *Mode* (cooperation, competition; within-subjects), *Target presence* (present, absent; within-subjects), *Social presence* (visually absent, schematic face, real face, confederate; between-subjects), and *Order* (cooperation first, competition first; between-subjects). Results showed two significant interactions, one between *Mode* and *Order* [$F(1,136)=34.07$, $p<.001$], as participants were faster for the second mode compared to the first mode, and one between *Social presence* and *Order* [$F(3,136)=2.94$, $p<.05$], as participants in the schematic face condition were much faster when competing first as compared to when cooperating first. Thus, both of our factors of interest, mode and social presence, interacted with order, giving rise to different results based on which mode occurred first. This presents a confound in our experiment, as any performance differences between modes and social presence conditions may not necessarily be attributable to our manipulations, but rather to the order of presentation. Because of this, we only considered participants' first modes in subsequent analyses, treating *Mode* as a between-subjects variable.

Table 3. Depicts participants' mean *accuracies* (with standard error of the means underneath) for their *first mode*

	Cooperation		Competition	
	Target	No Target	Target	No Target
Visually Absent	88.2% (2.5%)	95.2% (3.9%)	85.7% (2.5%)	93.9% (2.7%)
Schematic Face	87.7% (1.5%)	96.1% (2.7%)	86.7% (2.7%)	95.5% (3.3%)
Real Face	88.2% (2.6%)	96.9% (3.6%)	87.2% (3.5%)	93.9% (3.3%)
Confederate	89.1% (2.5%)	97.6% (3.5%)	86.7% (3.4%)	93.2% (4.5%)

Table 4. Depicts participants' mean *reaction times* (with standard error of the means underneath) for their *first mode*

	Cooperation		Competition	
	Target	No Target	Target	No Target
Visually Absent	632ms (18.4ms)	708ms (20.2ms)	558ms (16.8ms)	623ms (19.0ms)
Schematic Face	590ms (16.2ms)	658ms (19.3ms)	579ms (16.4ms)	644ms (18.9ms)
Real Face	586ms (10.6ms)	662ms (15.3ms)	585ms (19.6ms)	672ms (26.5ms)
Confederate	600ms (17.0ms)	669ms (20.5ms)	561ms (13.8ms)	634ms (15.6ms)

Table 5. Depicts participants' mean *accuracies* (with standard error of the means underneath) for their *second mode* (no longer considered in subsequent analyses)

	Cooperation		Competition	
	Target	No Target	Target	No Target
Visually Absent	86.2% (2.6%)	92.5% (3.0%)	86.7% (3.1%)	95.0% (3.8%)
Schematic Face	86.7% (3.4%)	95.2% (4.1%)	84.7% (3.6%)	93.6% (2.8%)
Real Face	87.7% (3.1%)	92.5% (3.6%)	86.2% (2.3%)	93.2% (3.3%)
Confederate	88.2% (2.4%)	95.2% (5.0%)	88.7% (2.3%)	95.8% (4.2%)

Table 6. Depicts participants' mean *reaction times* (with standard error of the means underneath) for their *second mode* (no longer considered in subsequent analyses)

	Cooperation		Competition	
	Target	No Target	Target	No Target
Visually Absent	540ms (14.9ms)	596ms (17.0ms)	592ms (12.9ms)	659ms (14.1ms)
Schematic Face	584ms (17.9ms)	640ms (21.4ms)	558ms (19.5ms)	600ms (17.4ms)
Real Face	581ms (18.6ms)	660ms (25.7ms)	563ms (14.6ms)	633ms (16.4ms)
Confederate	570ms (22.4ms)	627ms (25.7ms)	542ms (19.1ms)	593ms (19.8ms)

Data Analyses

Accuracy. We ran a repeated-measures ANOVA on accuracy with *Mode* (cooperation, competition,) and *Social presence* (visually absent, schematic face, real face, confederate) as between-subjects factors, and *Target presence* (present, absent) as a within-subjects factor. We found a main effect of *Mode* [$F(1,136)=8.08$, $p<.01$], such that participants who were told that they were cooperating (92.8%) were significantly more accurate than participants who were told that they were competing (90.7%). We also found a main effect of *Target presence* [$F(1,136)=363.27$, $p<.001$], as participants were more accurate to determine the absence of a target (95.2%) as compared to the presence of a target (87.2%; all other *Fs*<2.5, all other *ps*>.1; see Figure 5).

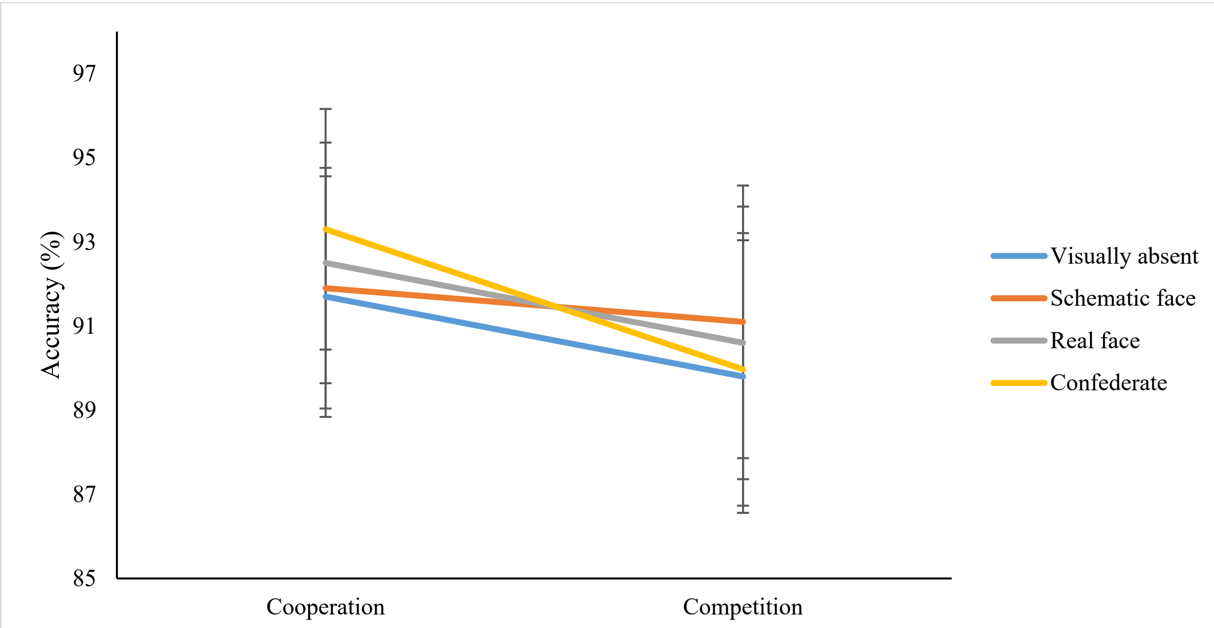

Figure 5. Average accuracy for cooperation and competition modes under each implied social presence condition, collapsed across target-present and target-absent trials. Error bars represent standard error of the mean, calculated as one average for all cooperation and another for all competition trials, as mode was our significant factor.

Reaction times. Next, we ran a repeated-measures ANOVA on mean RTs as a function of *Mode* (cooperation, competition), *Social presence* (visually absent, schematic face, real face, confederate), and *Target presence* (present, absent). We found a main effect of *Mode* [$F(1,136)=5.85$, $p<.05$], such that participants who were told that they were competing (606.5ms) were significantly faster than those who were told that they were cooperating (638.5ms). We also found the typical effect of *Target presence* [$F(1,136)=466.43$, $p<.001$], as participants were faster for target-present (586.0ms) compared to target-absent (659.0ms) trials (Wolfe, 1994, 2010). All other *Fs*<3, *ps*>.07 (see Figure 6).

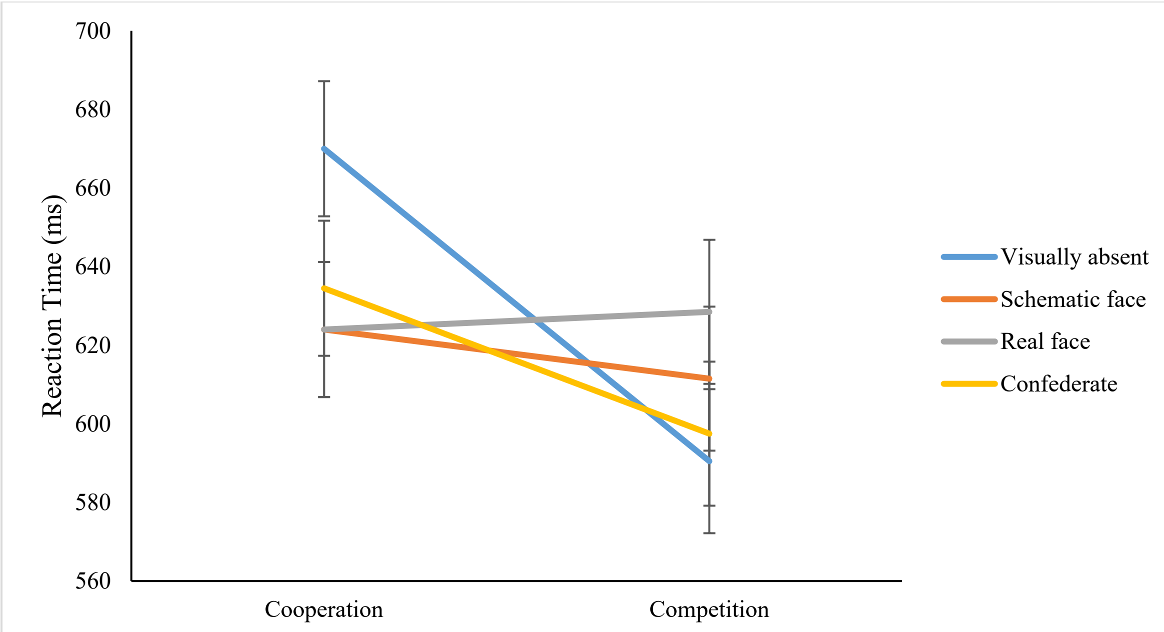

Figure 6. Average reaction time (ms) for cooperation and competition modes under each implied social presence condition, collapsed across target-present and target-absent trials. Error bars represent standard error of the mean, calculated as one average for all cooperation and another for all competition trials, as mode was our significant factor.

In sum, while we found no difference across the individual levels of social presence for accuracy and RT analyses, the general data pattern replicates prior findings when participants are physically cooperating or competing with another person, with more accurate responses when cooperating (A. A. Brennan & Enns, 2015), and faster responses when competing (Niehorster et al., 2019). These findings beg the question of whether our data patterns are actually due to the implied interaction we instilled in participants, or due to the mere act of winning points. To assess this alternative possibility, we ran four additional ANOVAs, two for accuracy and two for RTs. The analyses compared the condition where participants received points with no implied participant interaction against the cooperation and competition groups separately, collapsed across the four levels of social presence. If our findings are due to the mere act of winning points, then we should see no differences in RT and accuracy between those who were told they were interacting with a partner and those who were not. However, if our narrative of playing with a partner does indeed affect attention, then we should expect to see differences in RTs and/or accuracy across those who were told they were interacting with a partner and those who were not.

Table 6. Depicts baseline participants' mean *accuracies* (with standard error of the means underneath) for *both modes*

	First Mode		Second Mode	
	Target	No Target	Target	No Target
Points	84.7% (2.1%)	93.9% (4.2%)	82.9% (2.9%)	92.5% (3.6%)
Baseline	93.2% (2.5%)	98.5% (3.0%)	90.4% (2.7%)	96.6% (3.9%)

Table 7. Depicts baseline participants' mean *reaction times* (with standard error of the means underneath) for *both modes*

	First Mode		Second Mode	
	Target	No Target	Target	No Target
Points	619ms (17.1ms)	712ms (22.8ms)	564ms (15.6ms)	624ms (16.4ms)
Baseline	707ms (16.4ms)	835ms (16.4ms)	681ms (23.5ms)	820ms (33.3ms)

Cooperation versus points. A repeated-measures ANOVA was run on accuracy scores with *Mode* (cooperation, points) and *Target presence* (present, absent), that returned a main effect of *Mode* [$F(1,85)=6.88$, $p=.01$], in that those who were told that they were cooperating with another person were more accurate (92.8%) than those who received points with no implied partner (89.8%; interaction between *Mode* and *Target presence* was not significant, $F<1$, $p>.8$). In contrast, the same repeated-measures ANOVA with RTs as the dependent variable did not show a difference between *Modes* [$F(1,85)=2.00$, $p>.1$], nor was there an interaction between *Mode* and *Target presence* [$F(1,85)=3.29$, $p>.07$].

Competition versus points. A repeated-measures ANOVA was run on accuracy scores with *Mode* (competition, points) and *Target presence* (present, absent). Here, we did not find an effect of mode on accuracy ($F<1$, $p>.4$). However, the repeated-measures ANOVA on RT with *Mode* (competition, points) and *Target presence* (present, absent), did return a significant effect of *Mode*, as those who were told they were competing (606.5ms) were significantly faster than those who merely received points [665.5ms; $F(1,93)=7.91$, $p<.01$].

In sum, participants who were told they were cooperating with a partner were significantly more accurate than those who were not under the impression of playing with a partner, while those who were told they were competing with a partner were significantly faster than those who were not.

Points versus baseline. Do points alone also affect performance (RTs/Accuracy)? To check, we ran two additional analyses, one for accuracy and one for RTs, again as a function of *Mode* (points, baseline) and *Target presence* (present, absent). We found that participants who did not receive points (96.4%) were significantly more accurate than participants who received points [89.8%; $F(1,42)=24.10$, $p<.001$], but were significantly slower (771.0ms) than those who received points [665.5ms; $F(1,42)=19.10$, $p<.001$]. Additionally, we found a significant interaction between *Target presence* and *Mode* in the RT [$F(1,42)=4.19$, $p<.05$] ANOVA, such that RT was slowest for target-absent trials in the baseline condition. (Main effect of target presence RT: [$F(1,42)=163.39$, $p<.001$]; accuracy: [$F(1,42)=99.21$, $p<.001$]).

Thus, our work suggests that merely awarding points leads to differences in response patterns, however the act of implying to participants that they are completing the task with another leads to further differences in performance.

Discussion

We sought to investigate the effects of implied social presence and implied social interaction on attention with the use of an online visual search task. We posited that if virtual implied cooperation and competition affect attention in the same way that they do between two physically present individuals, then participants will be faster and less accurate when competing as compared to when cooperating (Niehorster et al., 2019), and further that when compared to the points condition, the cooperation group will be faster and more accurate (A. A. Brennan & Enns, 2015; Wahn et al., 2017), while the competition group will faster but less accurate (Niehorster et al., 2019). We also hypothesized that if the increase in realism of the visual depiction of the implied partner truly captures an increase in social presence, then there will be larger performance differences between cooperation and competition between those performing the visual search task under higher as opposed to lower levels of implied social presence. Our results indicated that participants who were told that they were competing with a partner were faster but less accurate than participants who were told they were cooperating with a partner. Although we did not find attentional differences between our different levels of implied social presence, our follow-up analyses with the points condition revealed that participants who were told they were cooperating with a partner were significantly more accurate than those who merely received points, while those who were told they were competing with a partner were significantly faster than those who received points. Finally, when comparing our two baseline conditions to each other, we found that participants who received points were significantly faster but less accurate than those who searched without receiving any feedback. These data findings yield three important implications, detailed below.

First, the results of the present study extend what we currently know about the ways in which cooperation and competition affect attention during in-person lab tasks, such that we found similar data patterns of faster but less accurate responses when competing versus cooperating in an online, virtual setting with only an implied partner (Niehorster et al., 2019). Our results suggest that the nature of a social interaction, such as cooperation and competition, can systematically cause people to change their search strategy even on a virtual platform when no real partner is present. This finding adds to our current knowledge regarding the ways in which psychological phenomena translates from the lab to online. Our work dovetails with a recent series of replication studies on various psychological effects (e.g. dysfluency engages analytic processing, less-is-better effect, effect of framing on decision making, etc.), in which researchers investigated the replicability of experiments across settings (R. A. Klein et al., 2018). Out of the 28 studies replicated, researchers only found one result that differed significantly between the lab and online administration of the tests, suggesting that, by and large, results are reproducible across these two settings (R. A. Klein et al., 2018). Our finding thus adds to a growing body of work by indicating that the study of implied social interactions can also be feasibly manipulated online, and provides additional support for other researchers to pursue online testing. By not being constrained to a physical lab space, researchers will be able to recruit from a wider pool of participants in terms of age, education level, and geographic location, at more flexible times of the day, and at potentially lower costs. Currently, most psychological testing is performed on Western individuals, and almost all research published by a leading journal in the field, *Psychological Science*, has been performed on WEIRD (Western, Educated, Industrialized, Rich, and Democratic) populations (Rad et al., 2018). While psychologists tend to use this data to make inferences about the population as a whole, cross-cultural research has demonstrated that this is not always sensible (Chua et al., 2005; Masuda et al., 2020). For example, it has been shown that American and Chinese individuals attend to scenes differently, such that while Americans fixate more on focal objects, Chinese people attend more to the background (Chua et al., 2005). This attentional difference would not have been uncovered had researchers not expanded their work to include non-WEIRD samples; as we have now demonstrated, implied social interactions can feasibly be manipulated over a virtual format, thus future researchers should feel more confident in the veracity of online testing to expand data acquisition to a wider pool of participants.

The second implication of our work concerns our manipulation of social presence. Specifically, while our original analyses were unable to distinguish whether our manipulation of online implied social presence affected attention, when comparing the performance of those who were under implied social presence to those who merely received points, a difference in performance was revealed, suggesting that there is little need for a visual representation of one's partner to elicit changes in performance. Our results build on prior evidence indicating that the threshold to suggest a social presence is actually quite low (Bateson et al., 2006; Dahl et al., 2001; Ernest-Jones et al., 2011). Research occurring in-person has manipulated social presence in various ways, including allowing participants to enter a restroom that is either open or closed to the public (Dahl et al., 2001), and placing eye-like stimuli in specific experimental locations (Bateson et al., 2006; Ernest-Jones et al., 2011; Francey & Bergmüller, 2012). Recall, Dahl and colleagues (2001) were able to demonstrate that participants completing the same potentially embarrassing act reported different levels of embarrassment depending on whether there was a chance of encountering another individual, which was interpreted as a result of an increased level of imagined social presence (Dahl et al., 2001). Social presence has also been induced by simply placing eye-like stimuli nearby; in the presence of images of eyes, researchers have demonstrated people donate more to charities and are more likely to clean up shared spaces (Bateson et al., 2006; Ernest-Jones et al., 2011; Francey & Bergmüller, 2012). Moreover, Tufft and colleagues (2015) have shown that a simple change in narrative about the social context of the same visual stimulus can suggest a social presence. They employed a visual cueing paradigm by asking participants to respond to targets that were either cued or not by a circle, and manipulated whether participants were told that the cue was connected to another person's gaze versus generated by a computer (Tufft et al., 2015). They found that participants displayed greater inhibition of return (IOR), such that they were slower to turn their attention back to a previously-attended location, when a cue was imbued with a social context (Tufft et al., 2015). This finding provides support for a phenomenon termed social IOR, whereby people are slower to attend to a location that another person has just attended to (Tufft et al., 2015). Thus, it may be because of this low threshold for suggesting a social presence that we did not find a difference in performance between our four levels of implied social presence.

Perhaps underlying our finding is the phenomenon of joint perception, whereby we believe that we are experiencing something at the same time as another person (Richardson et al., 2012). In our cooperation and competition conditions, we told participants that they were playing with a partner, thus suggesting to them that they were experiencing joint perception – a suggestion that was not present in the points condition. To demonstrate the effects of joint perception on attention, researchers employed the same visual cueing paradigm as Tufft and colleagues (2015), however they manipulated whether participants were led to believe that they were performing the same task or a different task as their implied partner (Gobel et al., 2018). Here, the data indicated that participants displayed greater social IOR only in cases where they were told that they were engaging in the same task as their partner (Gobel et al., 2018). As such, the phenomenon of joint perception can lead to fundamental changes in attention and cognitive processes. Thus, it may be participants' added belief of playing with or against another person that led to the differences in attention that we observed between the cooperation and competition conditions when compared to the points condition.

The narrative that we present to participants is therefore important in influencing their attention, and we have found that this is the case even over an online format. Crucially, we were able to add to our current understanding of the attentional differences between cooperation and competition in a visual search task by disentangling the direction of the differences in reaction time and accuracy measures when compared to a baseline condition. Namely, we have shown that while competition plays a larger part in increasing people's speed of responding, cooperation plays a larger role in increasing people's accuracy. Moreover, we have demonstrated that implying a social presence is easy to implement experimentally, while providing support for the phenomenon of joint perception.

The third and final implication of our work relates to our finding that receiving points results in faster but less accurate performance than not receiving any feedback. Prior research suggests that receiving feedback, either positive or negative, increases motivation (Fishbach et al., 2010; Woolley & Fishbach, 2018). Our finding further supplements this body of research by suggesting that motivation may be the mechanism driving our finding, as we have shown that the mere act of receiving points can fundamentally change participants' search strategy. This is important for future work, such that researchers should take into consideration the relationship between motivation and search strategy when designing experiments investigating attention with the use of feedback. Moreover, researchers should take care when comparing attention findings across studies who do and do not incorporate providing feedback in their experimental design, as conclusions drawn may be due to the presence or absence of feedback as opposed to key experimental manipulations.

Limitations and Future Research

No study is without its limitations. For one, we experienced a fairly high attrition rate, however when considering prior work on online testing, we find that our attrition rate (33%) is comparable to that found from a similar participant pool (25%; Gould et al., 2015), and is much lower than that found from other online experiments (79%; Dandurand et al., 2008). Moreover, due to the virtual nature of our experiment, we were not able to control for screen size, computer type, participant distance from the screen, and eye movements. However, in spite of these limitations, we found data patterns which replicate prior findings, such that participants who competed were faster but less accurate than participants who cooperated (Niehorster et al., 2019), and target-present trials were responded to faster than target-absent trials (Wolfe, 1994). This suggests that implied social interactions, as well as attention, can indeed be assessed both by using a visual search task and over an online format. Future work can implement our manipulations in-person and employ an eye-tracker to address these potential limitations. As previous research on social attention has found that certain social information such as faces and facial features have greater effects on overt when compared to covert attention (Gobel & Giesbrecht, 2020; Pereira et al., 2019), it is possible that any attentional differences between our levels of implied social presence may be uncovered only once overt attention is also considered and analyzed.

In sum, our work demonstrates that the study of implied social interactions can be extended to an online format, that it may not require much for researchers to be able to imply social presence to participants, and that the mere act of receiving feedback on performance may modulate motivation or alter search strategies. To our knowledge, we are the first to have studied implied social presence and interactions using an online format, paving the way for future researchers to investigate these phenomena using virtual methods. Our work has demonstrated that cognitions regarding our social environment can be manipulated virtually, as well as shape the ways in which we pay attention to the world around us.

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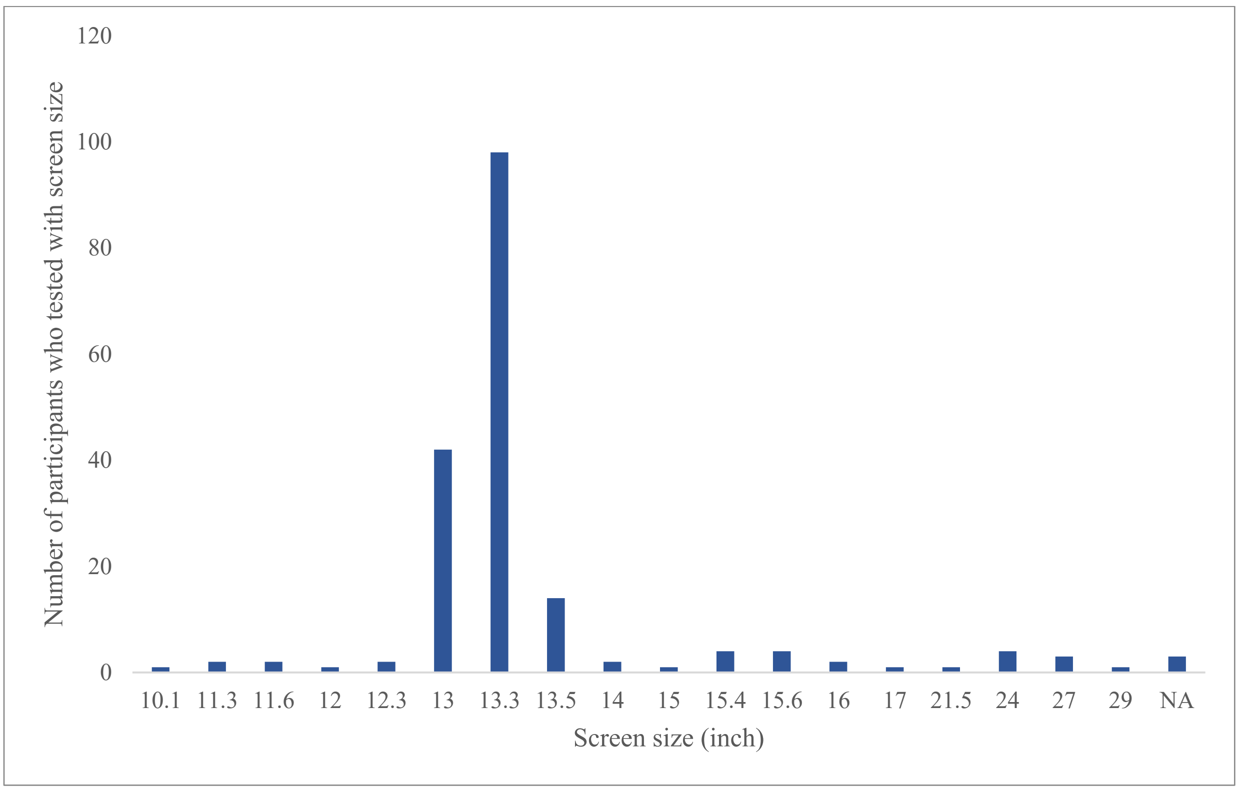
Appendix A

Table displaying the number of participants who used each operating system/browser combination on top, and the average value between reaction time variability and visual duration variability on the bottom (Bridges et al., 2020).

	MacOS	Windows
Chrome	163 6.02ms	20 8.10ms
Firefox	4 4.79ms	1 6.05ms

Histogram displaying the different screen sizes used by participants.



Appendix B

Table displaying the number of participants per experimental condition who used their own thresholds.

	Target-present trials	**Target-absent trials**
Cooperation	64/68	64/68
Competition	73/76	72/76
Points	3/19	4/19
Baseline	19/25	20/25

Appendix C

Pie chart displaying the proportion of data lost per reason for attrition.