When Sharing Attention Does Not Help: Reduced Attention Effect in Pairs

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Abstract

Research has generally suggested enhanced cognitive performance when performing jointly with others in social settings. However, the interpersonal influence on visuospatial attention was not well understood. With a newly developed *dual attention* paradigm, we investigated how paying attention to the same spatial location with another person affects one's attention performance. Participant pairs independently performed go/no-go tasks to visual targets while sustainedly attending to same or different locations, and showed reduced attention effects when sharing spatial attention (Experiment 1, $N = 40$). This *dual attention* effect relied on the presence of another individual performing a similar task, being reversed when participants performed the same task in isolation (Experiment 2, $N = 38$), and persisted under an increased perceptual load (Experiment 3, $N = 45$). These data showed a diminishing effect of shared attention, likely driven by stronger response inhibition or increased mentalizing/monitoring when people attended together.

Statement of relevance

Paying attention towards the same spatial locations with other individuals is an essential component of most human social interactions. We do this since childhood, while trying to learn from our parents, and continue doing it throughout our lifetime. Examples include a group of students attending together to a lecture and several workers monitoring a product in an industrial assembly chain. This topic is highly relevant to research fields involving social interactions and research questions on fundamental cognitive functions (such as attention and memory). The present article improves our understanding about how human attention is shaped when people

perform tasks together. We show that attention performance is impaired when people jointly attend to the same spatial locations. These findings have ubiquitous real-life implications, and may shed more light on how to optimize daily performance in environments such as classrooms and working spaces.

Keywords

Visuospatial attention, dual attention, interpersonal processes, visuomotor priming, social attention

Introduction

Humans are social animals immersed in social interactions and regularly performing tasks with others. For these interactions to be successful, people need to attend to spatial locations with other individuals. A group of students paying attention to a teacher and a couple of workers monitoring a product on an assembly chain represent only a few examples. However, the cognitive implications of this specific aspect of our social life are not well understood. Here we investigated whether paying attention towards the same spatial location with another person affects one's attention performance.

Since the first year of life, we follow other's gaze and jointly attend to objects in the environment with them. Termed joint attention (Frischen et al., 2007; Mundy & Newell, 2007), this skill facilitates sharing, coordinating and cooperating in the social world (Tomasello et al., 2005). Joint action research also illustrated that one can process another individual's task features as one's own when working together (*task*

co-representation account), even if it does not benefit one's own behaviour (He et al. 2011; Knoblich & Sebanz, 2006). Recent findings showed that, without gaze following or joint action, the sole knowledge of paying attention to the same objects or tasks with other individuals (i.e. shared attention; Shteynberg, 2015, 2018) is sufficient for leading to preferential allocation of cognitive resources and better performance. However, research has not investigated how the associated visuospatial attention performance differs between attended and unattended spatial locations under shared attention. The enhanced attention performance for attended locations is one of the most fundamental aspects of human behaviour thus required further research from the shared attention perspective.

Previous literature examined attentional allocation in hierarchical stimuli with a joint Navon task (Böckler et al., 2012). There, participant pairs viewed global letter stimuli made of local letters (e.g. a big "S" made of small "E"s) and focused on letter identities at the global or local level. While the global advantage was maintained, slower responses were found when two participants attended to different levels, showing a conflict of attentional focuses (Böckler et al., 2012; Böckler & Sebanz, 2012). The temporal aspect of visual attention was also studied in social settings. Inhibition of return (IOR) is a suppression of processing of stimuli recently being attended (Klein, 2000). When two participants worked together, IOR was found for locations previously attended by another person (Welsh et al., 2005, 2007). Interestingly, this social IOR was dependent on participants' belief and was found to be weaker when visual cues preceding targets were believed to be computer-generated rather than indicating another individual's overt attentional focus (Gobel et al., 2018).

Despite these important findings, additional research was needed to examine the social modulation of spatial attention performance. Theories proposed to explain interpersonal influences often pointed towards shared representation of task requirements and performance enhancement (e.g., Knoblich & Sebanz, 2006; Shteynberg, 2015; however, see Mairon et al., 2020). Yet, visuospatial attention performance in social settings has been largely missing from the picture. Some studies addressed effects of shared attentional focus (e.g. Lachat et al., 2012; Wolf et al., 2016) but did not investigate the spatial attention effect per se (i.e. the performance difference between attended and unattended conditions). The current study investigated the social modulation of spatial attention effects (termed *dual attention*). The sustained visuospatial attention paradigm (Eimer, 1996) was adapted for participant pairs (i.e. *dual attention paradigm*; *Fig. 1*), with two individuals independently performing go/no-go tasks to visual targets while deploying sustained attention to the same or different spatial locations. If dual attention, as suggested by most social attention theories, benefits from shared experience, an enhanced spatial attention effect would be expected when people shared their attentional locus.

Fig. 1. Stimuli and trial sequences. Participant pairs (Experiments 1 and 3, low and high task loads respectively) or individuals (Experiment 2) performed covert sustained visuospatial attention tasks (go/no-go responses). Participant pairs could attend to the same side or opposite sides of a screen.

Experiment 1

Method

Participants

Twenty-four volunteer pairs with normal or corrected-to-normal vision participated. Data from 40 participants (32 females, 8 males; 32 right-handed; aged 21.1 ± 3.0 years) were analysed after 8 participants being excluded due to low accuracies ($< 75\%$) in any design cell. Given that there was no previous literature on the current research topic, the sample size was estimated with a power analysis for a paired samples *t*-test on the contrast of interest (i.e., the attention effect changes when the attentional loci were shared vs. unshared by the participants), targeting a medium to large effect size ($d = 0.45$) and an alpha criterion of 0.05. The result suggested a sample size of 40 in order to achieve a power of 80% to detect the targeted effect.

Twenty-four volunteer pairs with normal or corrected-to-normal vision participated. Data from 40 participants (32 females, 8 males; 32 right-handed; aged 21.1 ± 3.0 years) were analysed after 8 participants being excluded due to low accuracies ($< 75\%$) in any design cell. Participants in each pair reported not having a close relationship. Ethical approval and informed consent were obtained.

Materials and procedure

Participant pairs sat next to each other in front of a computer monitor at a viewing distance of 70 cm and independently performed sustained visuospatial attention tasks. There were four two-block sessions, each block having 160 trials, with

attending instructions varying between sessions. In each session, each participant in a pair covertly attended to one side of the screen (50%:50% probability), resulting in the pair attending to the same side (attention shared) or different sides (attention not shared) of the screen with equal probabilities. Each participant acknowledged awareness of the other person's task.

The two participants in a pair performed discrimination tasks (go/no-go) with different assigned targets. Stimuli were large/small circles and squares. Each participant performed a go/no-go task. Each person was assigned one shape as their shape feature (e.g. circle) and to quickly respond to the large items of that shape (targets; e.g. large circles) presented in either side of the screen and withhold responses to other stimuli (non-targets; e.g. small circles) and the other shape (e.g. square). The large stimuli subtended $4.57 \times 4.57^\circ$, while the small ones $2.38 \times 2.38^\circ$ (30% of the area of a large stimulus), presented in white against a black background.

In each block, participants were requested to fixate on a white fixation cross ($0.54 \times 0.54^\circ$) at the screen centre throughout the block. Each trial randomly displayed one stimulus 8.68° (centre-to-centre) to one side of the screen for 150ms, followed by an interval of 1,350ms. For each shape feature, the attended side contained 75% of the targets (attended trials) and 25% of the non-targets (unattended trials), while the other side contained 25% of the targets and 75% of the non-targets. Participants responded as quickly as possible (within 1,000 ms) whenever detecting a target by pressing a mouse button (the participant on the right) or the spacebar on a keyboard (the person on the left). Each experimental session had eight blocks, varying the instructed focus of attention (i.e., along a specific block, the attended side for each participant could be as follows: P1:left / P2:left, or P1:left / P2:right, or P1:right / P2:left, or P1:right / P2:right;

P1=Participant 1, P2=Participant 2). These task instructions changed every two blocks. Each participant was informed about the experiment partner's instructions at the beginning of each experimental block. They had to acknowledge reading the instructions regarding the experiment partner's task. Several questionnaires were also completed (see Supplemental Material for details).

Statistical analyses

All analyses were performed using R (version 1.1.456) and RStudio (RStudio Team, 2016). Accuracies and reaction times (RTs) were analysed with analyses of variance (ANOVAs) on means (R package 'ez'; Lawrence, 2016) and robust methods on 20% trimmed means (R package 'WRS'; Wilcox & Schönbrodt, 2014). The latter works well both in the presence and absence of violations of statistical assumptions and increases statistical power and robustness over the arithmetic mean (Field & Wilcox, 2017; Wilcox, 2012). Statistical contrasts with the percentile bootstrap method on 20% trimmed means (Rousselet, Pernet, & Wilcox, 2019) were used to follow up ANOVA results to assess their robustness to outliers and to assumption violations. The percentile bootstrap results were presented as differences between trimmed means $\hat{\psi}$, the associated bootstrap 95% confidence intervals (95% CIs, reported simply as "CI"s below), and *p*-values. For relevant statistical interactions, Bayes factors were computed (R package 'BayesFactor'; Morey & Rouder, 2018) with the default prior (Jeffreys-Zellner-Siow) following the suggestion for situations when no prior information is available (Wagenmakers et al., 2018). Figures were made using the R packages 'yarr' (Phillips, 2017) and 'ggplot2' (Wickham, 2016).

Results

Participants showed high hit rates (97.1%, CI [95.7%, 98.5%]) and low false alarm rates (1.9%, CI [1.4%, 2.3%]). The accuracy data were not analysed further due to the near-ceiling performance. RTs in go-trials with correct manual responses were analysed. 4.5% of the data were removed as outliers determined with a threshold of 2.5 times the Median Absolute Deviation (MAD) for each design cell (Leys et al., 2013).

Mean RTs data (*Fig. 2*) were submitted to a 2x2 repeated-measures ANOVA with within-subjects factors Attention (attended vs. unattended) and Sharing (shared vs. unshared). A significant main effect of Attention was observed, $F(1, 39) = 70.45$, $p < .001$, $\eta_G^2 = 0.068$, showing shorter RTs in the attended (411 ms, CI [396 ms, 426 ms]) than the unattended conditions (438 ms, CI [422 ms, 454 ms]). The main effect of Sharing was not significant, $F(1, 39) = 0.99$, $p = .325$ (shared 427 ms, CI [411 ms, 443 ms]) vs. unshared 423 ms, CI [407 ms, 438 ms]). Attention significantly interacted with Sharing, $F(1, 39) = 9.10$, $p = .004$, $\eta_G^2 = 0.004$. The attention effect was smaller when attention was shared (21 ms, CI [14 ms, 28 ms]), $F(1, 39) = 36.06$, $p < .001$, $\eta_G^2 = 0.04$, than when it was not shared (33 ms, CI [25 ms, 41 ms]), $F(1, 39) = 63.76$, $p < .001$, $\eta_G^2 = 0.10$. This reduction of the attention effect by sharing situations was termed *dual attention* effect in the current setup.

The results from the within-within design percentile bootstrap on 20% trimmed means showed consistent results with a significant main effect of attention ($\hat{\psi} = -53$ [-66, -41], $p = 0$), a non-significant main effect of Sharing ($\hat{\psi} = -8$ [-22, 5], $p = .223$), and a significant interaction ($\hat{\psi} = -12$ [-21, -3], $p = .006$). For the Bayes factors analysis, the

attention effect was computed (subtracting the RTs in the attended condition from the RTs in the unattended condition) and compared across sharing conditions. BFs remained insensitive. The data were only 2.267 times more likely under an attention effect modulation, than under the null model ($BF_{10} = 2.267$).

Discussion

Contrary to the prediction, Experiment 1 showed a reduced attention effect when the participant pairs attended to the same spatial locations than when their loci of attention differed, which effect was termed as dual attention effect. This added to the literature showing negative effects of shared experience (e.g. Mairon et al., 2020), and disagrees with most shared attention research. One potential explanation was that the dual attention effect was not socially driven. Instead, it could be elicited by probabilistic properties of the adapted task. It is typical to have more targets on the attended side of the screen to encourage sustained attention. Here, this was implemented for both participants with the overall stimulus distribution balanced by having the unattended side containing more non-targets. However, the trial target/non-target distributions differed between the shared and unshared conditions. This trial imbalance might have induced an unwanted attention bias and led to the current finding. Experiment 2 was employed to address this possibility.

Fig. 2. Results of Experiment 1. **(a)** Mean RTs as a function of Attention (attended vs. unattended), and Sharing (shared vs. unshared) conditions. The group means are displayed with 95% confidence intervals (CIs). **(b)** Mean attention effects in reaction times (RTs) (unattended minus attended) between Sharing (shared vs. unshared) conditions (displayed with 95% CIs). The attention effect is smaller in the shared condition than in the unshared condition. This modulation of attention effect by sharing situations was termed *dual attention* effect. **(c)** The attention effect in each participant, with lines representing paired observations. 27 out of the 40 analysed participants showed the same trend as the group mean.

Experiment 2

Experiment 2 tested solo participants with the same paradigm. If the finding obtained in Experiment 1 was due to the differential distribution of targets across attention sharing conditions, Experiment 2 should replicate this result. A social effect would be argued instead if the result would differ from that of Experiment 1.

Method

Participants and procedure

Forty-three individuals with normal or corrected-to-normal vision participated. Data from 38 participants (23 females, 15 males; 30 right-handed; aged 23.1 ± 4.2 years) were analysed with 5 participants being excluded from analysis due to accuracy below 75% in any design cell.

The stimuli and procedure were identical to those of Experiment 1, except that participants performed the task individually by responding to a single assigned target stimulus. Therefore, the “Sharing” factor reflected the unbalanced distribution of stimuli across attention sharing conditions in Experiment 1.

Results

Participants showed a high performance in the task (mean hit rate 97.4%, CI [96.0%, 98.7%]; mean false alarm rate 1.3%, CI [1.0%, 1.6%]). Due to the near-ceiling performance, accuracies were not further analysed.

RTs were analysed as in Experiment 1 (*Fig. 3*), with 5.1% of the data removed as outliers with the same 2.5 MAD protocol. The ANOVA factor names were kept identical to those in Experiment 1 to allow comparisons. There was a significant effect

of Attention (attended 441 *ms*, CI [423 *ms*, 458 *ms*] vs. unattended 457 *ms*, CI [440 *ms*, 474 *ms*]), $F(1, 37) = 54.20, p < .001, \eta_G^2 = 0.022$, but no effect of Sharing (shared 450 *ms*, CI [432 *ms*, 468 *ms*] vs. unshared 448 *ms*, CI [431 *ms*, 465 *ms*]), $F(1, 37) = 0.30, p = .585$. Importantly, the Attention x Sharing interaction was significant, $F(1, 37) = 33.74, p < .001, \eta_G^2 = 0.025$, and was in the opposite direction to that of Experiment 1. The attention effect was significant in the shared condition (33 *ms*, CI [26 *ms*, 41 *ms*]), $F(1, 37) = 78.05, p < .001, \eta_G^2 = 0.082$, but non-significant in the unshared condition (-1 *ms*, CI [-8 *ms*, 6 *ms*]), $F(1, 37) = 0.07, p = .780$.

The percentile bootstrap on 20% trimmed means showed the same results, namely a significant effect of Attention, $\hat{\psi} = 29$ [17, 43], $p = 0$, a non-significant effect of Sharing, $\hat{\psi} = -6$ [-17, 7], $p = .354$, and a significant interaction, $\hat{\psi} = -31$ [-42, -22], $p = 0$. Bayesian analysis provided extreme evidence for the attention effects difference between Sharing conditions, relative to the null model, given the data, $BF_{10} = 1,651,410$.

Fig. 3. Results of Experiment 2. **(a)** Mean RTs as a function of Attention and Sharing factors (95% CIs displayed). **(b)** Mean attention effects (unattended minus attended) between Sharing conditions (95% CIs displayed). The attention effect is smaller in the unshared than in the shared conditions. **(c)** The attention effect in each participant. 32 out of the 38 analysed participants showed the same trend as the group mean.

Contrasting attention effects (Experiments 1 vs. 2)

To compare the attention effects between paired and solo situations, mean RTs in Experiments 1 and 2 were submitted to a three-way mixed ANOVA with an additional between-subjects factor Pairing (paired vs. solo). A significant main effect of Pairing was found, $F(1, 76) = 4.59$, $p = .035$, $\eta_G^2 = 0.052$, due to longer RTs in Experiment 2 (449 ms, CI [432 ms, 466 ms]) than in Experiment 1 (425 ms, CI [410 ms, 440 ms]). More importantly, there was a significant three-way interaction, $F(1, 76) = 42.87$, $p < .001$, $\eta_G^2 = 0.013$, suggesting that the modulation of the attention effect by sharing differed between experiments (*Fig. 4*). The dual attention effect (i.e. the attention effect difference between sharing situations, unshared minus shared) was 12 ms (CI [4 ms, 21 ms]) when participants were paired (Experiment 1) but turned out to be -34 ms (CI [-46 ms, -22 ms]) in the solo situation (Experiment 2), showing opposite patterns across experiments.

The between-within-within percentile bootstrap on 20% trimmed means showed the same results, i.e. a significant effect of Pairing ($\hat{\psi} = 108$ [23, 197], $p = .014$) and a significant three-way interaction ($\hat{\psi} = 46$ [31, 65], $p = 0$). Bayesian analysis of the attention effect modulations also revealed the data were more likely under the Sharing x Pairing interaction than under the null, $BF_{10} = 2,254,602$.

Fig. 4. Results contrasting Experiments 1 (paired) and 2 (solo). **(a)** Mean attention effects (unattended minus attended) as a function of Sharing across experiments (i.e. Pairing: Experiment 1 paired vs. Experiment 2 solo). **(b)** Mean dual attention effects (attention effect differences, unshared minus shared) between experiments. Group means are displayed with 95% CIs.

Discussion

The result showed the opposite modulation pattern of the attention effect to that in Experiment 1. Instead of showing a reduction, the attention effect was significant in the “shared” condition but absent in the “unshared” condition. This pattern in fact could be explained by the trial distribution. In the “unshared” condition, both visual fields contained large stimuli with equal probabilities. Despite that only one shape requested manual responses, attention might not be well biased towards the field containing most of the targets. This is consistent with the goal-contingent bias notion (Folk et al., 1992) with the large size being the contingent feature and capturing attention.

More importantly, given that the social context of the task (the presence of task partners and their task demands) was the only difference between the two experiments, the data suggest that the dual attention effect (i.e. attention effect reduction) was indeed social in nature. The shorter overall RTs in Experiment 1 (paired) than in Experiment 2 (solo) agrees with the social facilitation (Zajonc, 1965) and shared attention (Shteynberg, 2015, 2018) theories, which predict better performance when people attend to the same task together. However, the reduced visuospatial attention performance in the shared condition contradicted these theories.

This dual attention effect found in Experiment 1 would unlikely be explained by social loafing either, which refers to reduced motivation and effort when people work collectively (Karau & Williams, 1993). First, the RTs were not prolonged in the shared condition, not showing a general reduced effort. Second, it has been shown that when participants performed different tasks and each individual's responses were identifiable, it was less likely for social loafing to occur (Harkins & Petty, 1982). To further exclude the possibility of social loafing, it was desirable to run another experiment with

increased task difficulty. Indeed, it has been shown that social loafing was reduced or even overturned with increased task difficulty (Harkins & Petty, 1982; Jackson & Williams, 1985). The Load theory (Benoni, 2018; Lavie, 2010; Murphy et al., 2016) also suggests that an increased perceptual load reduces processing of distracting information (task requirements related to another individual in this case) and could lead to weaker interpersonal influence.

Experiment 3

Experiment 3 increased perceptual load by making target and non-target stimuli more similar. Social loafing would be expected to be weakened by this perceptual load manipulation. Thus, if social loafing was the reason for the dual attention effect, the effect would be diminished or reversed in the current experiment. Alternatively, a dual attention effect unaffected by perceptual load would suggest that the interfering social information employs resources from a separate process or attentional capacity (Benoni, 2018; Murphy et al., 2016)

Method

Participants and procedure

Twenty-four participant pairs with normal or corrected-to-normal vision took part. Data from 45 participants (33 females, 12 males; 41 right-handed; age 23.5 ± 5.2) were analysed, with 3 participants being excluded from analysis due to accuracies below 50% in any design cell. This new accuracy threshold was adopted for the increased task difficulty. Participants in all pairs reported not having a close relationship.

The stimuli and procedure were identical to those of Experiment 1, with the exception being the increased size of the non-target stimuli (from 2.38 x 2.38° to 3.97 x 3.97°, now 75% of the area of the target stimuli).

Results

The mean hit rate (83.4%, CI [80.7%, 86.1%]) was lower, and the mean false alarm rate (4.6%, CI [3.8%, 5.3%]) was higher, than that in Experiment 1 (mean hit rate: 97.1%, CI [95.7%, 98.5%]; mean false alarm rate: 1.9%, CI [1.4%, 2.3%]) due to the higher task load. The 2 Attention (attended vs. unattended) x 2 Sharing (shared vs. unshared) ANOVA on mean accuracies did not find any main effect of Attention or Sharing, but revealed a significant interaction, $F(1, 44) = 10.52, p = .002, \eta_G^2 = 0.011$. This interaction was confirmed by the percentile bootstrapping on 20% trimmed means, $\hat{\psi} = 4.63 [1.57, 7.65], p = .003$. The attention effects showed opposite directions for unshared (attended 84.9% vs. unattended 81.7%; attention effect -3.2%, CI [-5.51%, -0.89%]) and shared (attended 82.8% vs. unattended 84.2%; attention effect 1.35%, CI [-0.88%, 3.58%]) conditions.

RTs were analysed as before after 5.0% of data were removed as outliers with the same 2.5 MAD protocol. Results replicated those of Experiment 1 (*Fig. 5*). There were a significant effect of Attention (attended 479 ms, CI [465 ms, 494 ms] vs. unattended 504 ms, CI [488 ms, 519 ms]), $F(1, 44) = 89.20, p < .001, \eta_G^2 = 0.048$, and a significant Attention x Sharing interaction, $F(1, 44) = 10.58, p = 0.002, \eta_G^2 = 0.005$. The same dual attention effect as in Experiment 1 was found, showing a smaller attention effect in the shared condition (17 ms, CI [10 ms, 23 ms], $F(1, 44) = 24.70, p < .001, \eta_G^2$

= 0.027) than in the unshared condition (32 *ms*, CI [25 *ms*, 39 *ms*], $F(1, 44) = 77.28$, $p < .001$, $\eta_G^2 = 0.070$). The main effect of Sharing was not significant (shared 486 *ms*, CI [472 *ms*, 501 *ms*] vs. unshared 497 *ms*, CI [476 *ms*, 514 *ms*]), $F(1, 44) = 3.63$, $p = .063$. This dual attention effect was not due to an accuracy-RT trade-off.

This pattern was confirmed by the robust method, which showed a significant effect of Attention, $\hat{\psi} = -45$ [-57, -35], $p = 0$, a non-significant effect of Sharing, $\hat{\psi} = 13$ [-2, 31], $p = .079$, and a significant interaction, $\hat{\psi} = -17$ [-25, -8], $p < .001$. The Bayesian analysis of the attention effects also supported this interaction with strong evidence, $BF_{10} = 13.8$.

Fig. 5. Results of Experiment 3. (a) Mean RTs as a function of Attention and Sharing (95% CIs displayed). (b) Mean attention effects (unattended minus attended) between sharing conditions (95% CIs displayed). The dual attention pattern replicated that found in Experiment 1. (c) The attention effect in each participant. 33 out of the analysed 45 participants showed the same trend as the group mean.

Contrasting attention effects (Experiments 1 vs. 3)

To compare Experiment 1 and Experiment 3, mean accuracies were submitted to a 3-way Mixed ANOVA, adding Load (Easy vs. Hard) as between-subject factor. This yielded a significant main effect of Load, $F(1, 83) = 77.00, p < .001, \eta_G^2 = 0.399$, given that participants performed better in Experiment 1 ($M = 97.14\%$, $95\%CI [95.74, 98.54]$) than in Experiment 3 ($M = 83.41\%$, $95\%CI [80.71, 86.11]$). The robust test ('*bwwwmcppb*' function; Wilcox, 2012) supported this result, $\hat{\psi} = 56.2 [43.3, 68.2], p = 0$. In addition, the classic 3-way ANOVA also yielded a significant interaction Attention x Sharing, $F(1, 83) = 13.25, p < .001, \eta_G^2 = 0.002$, but this was not the case for the robust test, $\hat{\psi} = 8.78 [-0.34, 12.9], p = .060$. Regarding this disparity, it should be mentioned that robust methods are generally preferred (and their results trusted more) over classic statistical tests, especially when addressing accuracies data, known to violate the normality assumption associated to the latter (Field & Wilcox, 2017).

Mean RTs in Experiments 1 and 3 were submitted to a three-way mixed ANOVA with a between-subjects factor Load (Easy vs. Hard). A significant effect of Load was obtained, $F(1, 83) = 39.78, p < .001, \eta_G^2 = 0.290$, showing longer RTs in Experiment 3 (492 ms , $CI [477, 507]$) than in Experiment 1 (425 ms , $CI [410, 440]$). The three-way interaction was not significant, $F(1, 83) = 0.21, p = .650$. The dual attention effect (i.e. the attention effect difference between sharing conditions, unshared minus shared) was comparable between Experiments 1 (12 ms , $CI [4, 21]$) and 3 (15 ms , $CI [6, 25]$).

The between-within-within percentile bootstrap on 20% trimmed means confirmed the above findings with a significant Load effect ($\hat{\psi} = -284 [-355, -205], p = 0$)

and a non-significant three-way interaction ($\hat{\psi} = 3 [-13, 18]$, $p = .734$). The absence of differential dual attention effect was also supported by Bayesian analysis, which moderately favoured the null model, relative to the Sharing x Load interaction, given the data, $BF_{10} = 0.243$.

Fig. 6. Results contrasting Experiments 1 (easy) and 3 (hard). (a) Mean attention effects (unattended minus attended) across sharing conditions and experiments (i.e. Difficulty: Experiment 1 easy vs. Experiment 3 hard). (b) Mean dual attention effects (attention effect differences, unshared minus shared) between experiments. Group means are displayed with 95% CIs.

Discussion

The result replicated the finding of Experiment 1, while a higher task difficulty was confirmed by the significantly longer RTs and lower accuracies. The absence of modulation of the dual attention effect by perceptual load agrees with earlier discussion dismissing a contribution by social loafing.

General Discussion

When visual attention was deployed by two individuals to the same location, visuospatial attention performance was impaired (i.e. the dual attention effect). The manipulations of social presence (Experiment 2) and perceptual load (Experiment 3) were both effective, as evidenced by the general slowing down without the social presence of another person and worse performance (lower response accuracy and longer RTs) in the harder task. The dual attention effect was not modulated by task difficulty yet relied on the presence of another individual sharing the visuospatial attention task. These findings suggest that the dual attention effect is a social phenomenon resistant to high perceptual load. However, in contrast to most of the findings on joint action and shared attention (e.g. Knoblich & Sebanz, 2006; Shteynberg, 2015), the current findings were not due to one individual representing both participants' task requirement or general performance enhancement with the presence of another acting person.

The dual attention effect could be explained by changes in response inhibition across attention sharing conditions. Evaluative pressure increases distractibility of irrelevant stimuli comprising features contingent to one's task set (Belletier et al., 2019;

Normand, Bouquet, & Croizet, 2014). This interference occurs at the response selection stage due to a greater visuomotor priming from the irrelevant (but contingent) stimuli (Normand et al., 2014). In the current paradigm, the contingent interference arose from another individual's targets, which shared a key feature (stimulus size) of one's own targets, leading to response priming that required inhibition. Furthermore, attending to the same spatial location with a task partner potentially caused an increased evaluative pressure (relative to the unshared condition), leading to higher distractability, a heightened contingent interference, and subsequently a higher level of response inhibition. This response inhibition was reflected in the impaired attention effect. It is worth noting that the attended location did not act as the contingent feature since that would predict a RT difference between the attention shared and unshared conditions, here absent. Instead, the attended spatial location served as "glue" that bound visual features together (Spence & Frings, 2020; Treisman & Gelade, 1980). A jointly attended location might make the features related to another person more distracting and harder to ignore, if they relate to one's current task. The need of visuomotor priming inhibition may also come from task co-representation and mentalizing. Co-representing a partner's targets could activate one's own target-relevant response (Knoblich & Sebanz, 2006) which, given the unbalanced trial distribution, was stronger and in more need of being inhibited in the shared than unshared attention conditions.

Moreover, it has been argued that jointly attending to the same spatial location increases bonding between the co-attending individuals and might induce mentalizing (Wolf et al., 2016). The knowledge of attending to the same spatial location with another person could possibly lead to cognitive processes similar to those involved in

joint attention, including mentalizing and monitoring the other individual, which are crucial for behavioural coordination (Mundy & Newell, 2007; Tomasello et al., 2005). These higher cognitive processes may consume mental resources and negatively impact on the attention performance.

The competition between mentalizing and dual attention is also consistent with the absence of modulation by perceptual load. The persistence of the dual attention effect under a high perceptual load suggests that the effect is unlikely a sensory-level process, and potentially higher in cognition (Handy & Mangun, 2000; Handy, et al., 2001). An alternative explanation of the high load data would be an efficient/automatic dual attention process, which does not require attentional resources (Benoni, 2018; Lavie, 2010; Murphy et al., 2016), in line with the features of joint attention (Frischen et al., 2007). However, this explanation does not agree well with the earlier suggestion of a higher cognitive dual attention process, thus less likely to be true.

Overall, the current study revealed a striking interpersonal influence on visuospatial attention (dual attention). This effect impaired attention performance when people attended to the same spatial location irrespective of perceptual load. These findings highlight the importance of examining visuospatial attention in future social interaction research.

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Ethics Statement

All the experiments received ethical approval from the Bournemouth University Ethics Committee.

Author Contributions

XH developed the research question. XH and JCAD contributed to the experimental design. All authors contributed to data collection. JCAD and XH analyzed the data. All authors contributed to the writing of the manuscript and approved the final version of the manuscript for submission.

Conflict of Interest Statement

The authors declare no conflicts of interest with respect to the authorship or the publication of this article.

Supplemental Material

Supplemental material can be found at the end of the current document. The data and code scripts used for the analysis here presented are available in the Open Science Framework repository, <https://osf.io/453sm/>

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Supplemental Material

Correlation Analysis

In Experiments 1 and 3, the participants also completed several questionnaires to assess some psychological traits and check their contribution to the dual attention effect. These included the *Individualism-Collectivism* scale (IND-COL; Singelis, Triandis, Bhawuk, & Gelfand, 1995), the *Autism-spectrum Quotient* (AQ; Baron-Cohen et al., 2001), and the *State-Trait Anxiety Inventory* (STAI; Spielberger, 1983).

IND-COL was completed before the computer-based trials to measure the degree to which participants saw themselves as members of a collective/social group (i.e., collectivism) or as independent selves (i.e., individualism). The scale has four dimensions, namely horizontal collectivism (HC), vertical collectivism (VC), horizontal individualism (HI), and vertical individualism (VI), with the horizontal feature representing equality among individuals and the vertical feature representing hierarchies. HC and VC scores have been shown to be highly correlated (e.g. Triandis & Gelfand, 1998), and they are typically merged into a combined Collectivism score (e.g., He et al., 2014). We used the same protocol, resulting in three measures, namely HI, VI, and the combined collectivism (COL). After the computer-based trials, AQ and STAI were completed consecutively. AQ has 50 items and measures autistic-like traits in general population. STAI has 40 items and assesses trait and state anxiety (20 items each).

Experiment 1

Six scores from the three questionnaires (HI, VI, COL; AQ; state anxiety, trait anxiety) were correlated to the dual attention effect, which was defined as the RT difference in

attention effects between sharing conditions. Spearman's rank correlations and Bayesian correlations with the Jeffreys-beta prior (Ly, Verhagen, & Wagenmakers, 2016) were employed. None of the questionnaires scores significantly correlated with the dual attention effect (*Table S1*). Due to technical issues with the data, or missing answers from the participants, the sample sizes of the correlations differed within each of the experiments reported below.

Experiment 3

The correlations were employed in the same way as in Experiment 1. None was statistically significant (*Table S2*).

Experiments 1 and 3 combined

Given that the same result patterns were obtained in RTs of Experiments 1 and 3, their data were pooled together to increase the sample size in further correlations. Still, no significant correlation was found (*Table S3*).

Table S1.

Experiment 1, correlations between the questionnaires scores and the dual attention effect

Scores	r_s	p	BF_{10}
Combined Collectivism (COL) ($N = 40$)	0.000	1	0.359
Horizontal Individualism (HI) ($N = 40$)	-0.081	.619	0.634
Vertical Individualism (VI) ($N = 40$)	-0.115	.479	0.538
Autism-spectrum Quotient (AQ) ($N = 39$)	0.063	.702	0.360
State Anxiety ($N = 39$)	-0.091	.583	0.357
Trait Anxiety ($N = 39$)	0.176	.276	0.904

Table S2.*Experiment 3, correlations between the questionnaires scores and the dual attention effect*

Scores	r_s	p	BF_{10}
Combined Collectivism (COL) ($N = 44$)	0.153	.320	0.503
Horizontal Individualism (HI) ($N = 44$)	0.096	.536	0.441
Vertical Individualism (VI) ($N = 44$)	0.106	.494	0.444
Autism-spectrum Quotient (AQ) ($N = 42$)	0.030	.849	0.345
State Anxiety ($N = 34$)	-0.106	.533	0.463
Trait Anxiety ($N = 34$)	-0.105	.531	0.479

Table S3.*Experiments 1 and 3 combined, correlations between the questionnaires scores and the dual attention effect*

Scores	r_s	p	BF_{10}
Combined Collectivism (COL) ($N = 84$)	0.067	.547	0.299
Horizontal Individualism (HI) ($N = 84$)	-0.080	.468	0.538
Vertical Individualism (VI) ($N = 84$)	-0.137	.213	0.568
Autism-spectrum Quotient (AQ) ($N = 81$)	0.025	.823	0.255
State Anxiety ($N = 73$)	-0.047	.685	0.316
Trait Anxiety ($N = 73$)	0.053	.646	0.260

Post-hoc simple main effects analysis

For all the experiments, post-hoc simple main effect analyses were conducted to examine the effect of Sharing separately in each of the Attention conditions. For this purpose, both ANOVA and the percentile bootstrap method on 20% trimmed means were employed. For the data in Experiment 1 (see Figure 2), both methods suggested a significant difference between the RTs to attended locations across Sharing conditions, $F(1, 39) = 6.33$, $p = .016$, $\eta_G^2 = 0.01$; $\hat{\psi} = -8.86$ [-15.6, -2.79], $p = .004$, due to slower RTs in the shared attention condition than in the unshared condition. RTs to unattended locations were not statistically different across Sharing conditions, $F(1, 39) = 0.20$, $p = .653$; $\hat{\psi} = 1.18$ [-7.89, 10.2], $p = .726$.

Experiment 2 (see Figure 3) showed a significant difference between the RTs to attended locations across Sharing conditions, $F(1, 37) = 15.51$, $p < .001$; $\hat{\psi} = 14.34$ [7.62, 20.11], $p = 0$. Responses were faster to stimuli displayed at the attended locations in the shared condition than in the unshared condition. In addition, RTs to unattended locations were slower in the shared condition than in the unshared condition, $F(1, 37) = 18.73$, $p < .001$, $\eta_G^2 = 0.03$; $\hat{\psi} = -16.79$ [-26.97, -6.95], $p = 0$.

In Experiment 3 (see Figure 5), RTs to attended locations were not statistically different across sharing conditions, $F(1, 44) = 0.20$, $p = .654$; $\hat{\psi} = -3.41$ [-12.75, 7.39], $p = .536$. In contrast, RTs to unattended locations were significantly faster in the shared condition than in the unshared condition, $F(1, 44) = 8.56$, $p = .005$, $\eta_G^2 = 0.03$; $\hat{\psi} = 15.13$ [5.29, 26.18], $p = .001$.

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