Category-specific effects of high-level relations in visual search

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Abstract

Recent empirical findings demonstrate that, in visual search for a target in an array of distractors, observers exploit information about object relations to increase search efficiency. We investigated how people searched for interacting people in a crowd, and how the eccentricity of the target affected the search (Experiments 1-3). Participants briefly viewed crowded arrays and had to search for an interacting dyad (two bodies face-to-face) among non-interacting dyads (back-to-back distractors) or *vice versa*, with the target presented in the attended central location or at peripheral locations. With central targets, we found a search asymmetry, whereby interacting people among non-interacting people were detected better than non-interacting people among interacting people. With peripheral targets, non-interacting targets were detected better than interacting targets. In Experiment 4, we asked whether these asymmetries generalized to object pairs whose spatial relations did or did not form functionally interacting sets (computer screen above keyboard). Results showed that non-interacting targets were detected better than interacting targets, whether presented in central or peripheral locations. Thus, the effect of relational information on visual search is contingent on both stimulus category and attentional focus. Across both stimulus categories (bodies and objects), search is facilitated when individual distractor-items can be organized in larger structured units (social interaction or functional set), effectively reducing the number of distractors. The presentation of social interaction at the attended (central) location breaks this search pattern by readily capturing an individual's attention.

Keywords: Visual search, asymmetry, social interaction, attention, eccentricity, spatial relation

Introduction

Each moment in the visual world is a cluttered scene, where structure emerges from the spatial relations between things. Spatial relations can also indicate social relationship. Proximity and *facingness*, the mutual perceptual accessibility of two people, are reliable cues of social interaction, which individuals readily exploit to detect and decipher social events (Papeo et al., 2017; Papeo et al., 2019; Quadflieg & Koldewyn, 2017; Vestner et al., 2019).

Visual search experiments have begun to unravel how the human visual system takes advantage of spatial relations between people to parse crowded scenarios (Papeo et al., 2019; Vestner et al., 2019, 2020; 2021). Visual search asymmetries are traditionally used to document the efficient processing of a class of stimuli (A), relative to another class (B). Finding a target A among a set of distractors Bs may be faster and/or easier than finding a target B among distractors As. When this kind of asymmetry is observed, it can be inferred that A carries features that makes it more salient to visual attention than B (Treisman & Souther, 1985; Wolfe et al., 2001). Using this test of search efficiency, Papeo et al. (2019) showed that, with fast presentation of crowded search arrays, participants were more accurate in reporting the target when it was a dyad of face-to-face –seemingly interacting– bodies (interacting dyad) among a set of non-interacting (back-to-back) dyads (distractors) than a non-interacting dyad among a set of interacting dyads. This effect was independent from set size (*i.e.*, number of distractors in the array), suggesting that interacting dyads *pop out* of the display, involving automatic covert attention (Treisman & Sato, 1990; Wolfe, 1994). The results of Papeo et al. suggested for the first time that two bodies in a spatial relation that cue interaction capture attention more strongly than the same bodies presented as unrelated (see also Vestner et al., 2019; Skripkauskaite et al., 2022).

This phenomenon has raised questions concerning its selectivity for social stimuli and whether facing dyads are indeed efficiently detected due to their ability to capture attention (Vestner et al., 2021; 2022).

Do interacting people truly capture attention? Papeo et al. (2019) showed a search asymmetry in favor of interacting dyads when the target was always presented at eight predictable locations (out of 16 locations in the array). This was compatible with an interpretation of the effect based on attentional capture, as capture is promoted when attention can be deployed to a limited set of locations in the array (Wolfe, 2007; Neider & Zelinsky, 2008). When, however, the task increased the need for searching through the distractors, to the detriment of immediate attentional capture, the opposite effect was found: more efficient search for non-facing dyads among facing dyads than *vice versa* (Papeo et al., 2019; Experiment 3). The latter pattern was more akin to what was observed with non-social relational stimuli. In particular, Kaiser et al. (2014) first reported that a target object was found more accurately and efficiently when distractor objects were presented in their typical spatial and functional arrangement, *e.g.*, a computer screen above a keyboard, a mirror above a sink, or a lamp above a table, as opposed to a computer screen below a keyboard, a mirror below a sink, or a lamp below a table (see also Kaiser et al., 2015; Kaiser et al., 2019; Stein et al., 2015). This effect was interpreted as the result of automatic grouping of two related objects into a unitary percept, which effectively reduced the number of units to process as distractors, and therefore improved search efficiency.

In sum, at the current state of knowledge, visual search through body dyads gives rise to seemingly incompatible effects: attentional capture yielding search asymmetry in favor of interacting dyads, and more efficient search for non-interacting dyads among interacting dyads than *vice versa*. Moreover, it is unknown to what extent the effects of social relations generalize to non-social relations, as search asymmetry has so far not been probed with object pairs. The current study sheds light on these questions.

Given that, in Papeo et al*.* (2019), interacting versus non-interacting dyads evoked one effect (search asymmetry in favor of interacting dyads) or the other (more efficient search for non-interacting dyads among interacting dyads than *vice versa*), we hypothesized that performance with body dyads could depend on how much the task favored immediate capture of attention *versus* how much it required search thought the distractors. To test this, we manipulated the location of the target, which could appear at the center *versus* the periphery of the search array. When the target is presented around central fixation, few (or no) distractors need to be processed to get to the target, and the resulting performance emphasizes differences in the capacity of the targets (interacting *vs.* non-interacting dyad) to capture attention. In contrast, interacting and non-interacting dyads are less visible and discriminable at the periphery, as eccentricity (i.e., the distance of a stimulus from central vision) reduces visual acuity (Carrasco et al., 1995; Carrasco & Frieder, 1997) and promotes visual crowding (Bouma, 1970; Whitney & Levi, 2011). Thus, when presented at peripheral locations, the capacity of a target to capture attention is reduced, and the visual search performance depends more heavily on how efficiently the participant can go through the array and reject the distractors. As a result, non-interacting dyads among interacting dyads may be found more efficiently than *vice versa*. The manipulation of configuration (interacting *vs.* non-interacting) and target eccentricity (central *vs.* peripheral) was repeated with interacting *vs.* non-interacting body dyads and with functionally interacting *vs.* non-interacting object pairs, to test whether the effects of social relations in visual search apply to other (non-social) higher-level relations.

This research was developed in four experiments. In Experiment 1, we studied the effects of target location (central *vs.* peripheral) in the search asymmetry between interacting (facing) and non-interacting (non-facing) dyads. The target could appear at one of eight locations, four around central fixation and four at more peripheral locations. To verify that our manipulation of target eccentricity (central *vs.* periphery) was effective, we used eye-tracking to make sure that participants maintained central fixation at the beginning of the trial. We studied whether the advantage for interacting dyads emerged selectively when the target appeared around central fixation, or it could also be found for targets at peripheral locations. To preview, results showed that interacting dyads were detected better than non-interacting dyads only when presented at central locations. The asymmetry was reversed in the direction of an advantage for non-interacting dyads when targets appeared at peripheral locations. Experiments 2-3 provided a replication of the results in Experiment 1 with small variations of the original task. In Experiment 4, participants were tested on the same task, also with functionally interacting versus non-interacting object pairs (e.g., computer above keyboard *vs.* computer below keyboard). Results showed that, irrespective of eccentricity, non-interacting targets were always found better than interacting targets. We propose that higher-level (social or non-social) relations between distractors generally benefit visual search by enabling grouping of single distractor items in larger meaningful units (social interactions for bodies and functional sets for objects). In addition, an eccentricity-dependent effect unique for social relations demonstrates that people readily attract attention when interacting.

Experiment 1

Interacting (*i.e.*, face-to-face) bodies in a crowded array are detected better than non-interacting bodies (Papeo et al., 2019; Vestner et al., 2019). This advantage has been interpreted as evidence for an automatic recruitment of attention by social interaction. Here we addressed how target eccentricity modulates this effect, by systematically varying the target location between center and periphery. Eye-tracking was used to control that the participants maintained central fixation when the trial began.

Methods

Participants

Twenty-four healthy participants (12 females; age *M* = 25, *SD* = 3.76) were recruited as paid volunteers. Participants had normal or corrected-to-normal vision and reported no psychiatric or neurological history or current medication. The sample size of 24 was estimated *a priori* with the package *BUCSS* (Anderson & Kelley, 2020), based on the results in Papeo et al. (2019; configuration by distractor orientation interaction in Experiment 1: $F = 8.43$; $\alpha = .05$; $\beta = 0.80$). All experiments were approved by the local ethics committee (Comité de Protection des Personnes Sud-Est II). Participants gave informed written consent before participation and were paid 10 euros at the end of the study.

Stimuli

Stimuli were search arrays displaying dyads of interacting and non-interacting bodies on a white background. Thirty-three dyads were created starting from 10 bodies in different biomechanically possible poses seen in left or right profile, for a total of 20 bodies. Bodies were gray-scale models created with Daz3D (Daz Productions, Salt Lake City, UT) and the MATLAB image-processing toolbox (The MathWorks, Natick, MA). Bodies were randomly combined in dyads. Each dyad included one body oriented leftward and one body oriented rightward, which could face toward (interacting dyad; Fig. 1A, left) or away from each other (non-interacting dyad; Fig. 1A, right). Distances between the two bodies were matched across interacting and non-interacting dyads, in terms of distance between the centers of the two bodies (interacting: $M = 210$ pixels, $SD = 1.47$; non-interacting: $M = 210$ pixels, $SD = 2.37$; $t(64) = 0.49$, $p > .250$), and distance between the two closest extremities of the two bodies (interacting: $M = 62.57$ pixels, $SD = 13.27$; non-interacting: $M = 62$ pixels, $SD = 13.43$; $t(64) = 0.17$, $p > .250$).

Each array was composed of two symmetrical halves separated by a central fixation cross (Fig. 1C). Each half was divided into 8 equally sized cells (two columns of 4 cells each), with slightly shifted onsets along the vertical and horizontal axes. Four dyads, all interacting or all non-interacting, appeared on one side of the array. The other side was the mirror version of the first. The two halves differed by only one cell: on either half, this cell featured one interacting dyad (the target) when all other cells featured non-interacting dyads (the distractors) (50% of trials), or one non-interacting dyad (the target) when all other cells displayed interacting dyads (the distractors) (50% of trials). In each array, the distractors could appear in any of the 16 cells, whereas the target could appear in only one of the eight cells on the two middle rows (see gray area in Fig. 1C). Within these eight locations, eccentricity was defined in terms of proximity to the central fixation cross: central locations corresponded to the four cells flanking the fixation cross; peripheral locations corresponded to the four cells at the lateral edges of the array. For each participant, we created a unique set of stimuli that contained 200 arrays with one interacting target among seven non-interacting distractors (interacting condition; Fig. 1C, left), and 200 arrays with one non-interacting target among seven interacting distractors (non-interacting condition, Fig. 1C, right). Targets occurred at central (50% of trials) or peripheral locations (50% or trials). At a distance of 60 cm, individual dyads subtended approximately 1.86° x 2.10° of visual angle (~0.76° x ~2.01° for a single body) and were separated by ~4.30° of visual angle. Thus, the distance between cells was about ten times the distance between bodies within a dyad, preventing the possibility of a dyad spanning two horizontally aligned cells. Central locations were within ~5.25° around the fixation cross; peripheral locations were the outer ~5.25° of the array. Arrays did not exceed 10.66° x 10.29° of visual angle.

Procedures

Participants sat on a footstool in a dark soundproof booth, at a distance of ~60 cm from a Tobii T60XL eye-tracker screen (60Hz sampling rate). The experiment began with the eye-tracker calibration, which involved fixating a series of crosses, as they appeared on the screen. After the calibration, participants were instructed to fixate the cross at the center of the screen to search for the only interacting dyad (i.e., the facing dyad) among non-interacting dyads (i.e., back-to-back dyads) or, in a separate block, for the only non-interacting dyad among interacting dyads. They had to report whether the target was on the left or right of the central fixation cross. Participants were instructed to fixate the central cross in order to begin the trial. The trial could not begin unless they fixated on the cross. This ensured that peripheral targets were indeed in the visual periphery when the trial started. Each trial began with a central fixation cross (200 ms) followed by a blank screen (700 ms) and a search array (800ms). After the search array disappeared, a blank screen was shown until the participant responded. The next trial began after 1400 ms. Participants were instructed to respond by pressing one of two keys (the “Z” key to respond “left” and the “1” key to respond “right”) on the computer keyboard, with their left or right index finger, respectively. The key assignment (responding “left” by pressing the left key with the left index finger and “right” with the right index finger on the right key) was the same for all participants to avoid stimulus-response incongruence. Participants were invited to take a break every 40 trials and in the interval between the two blocks. Each block began with a familiarization including 16 stimuli, 2 stimuli for each of the eight experimental conditions. The order of blocks (interacting target first or non-interacting target first) was alternated across participants. Stimulus presentation and recording of eye-tracking data were controlled through PsyScopeX (http://psy.cns.sissa.it/). The experiment lasted ~ 30 min.

Behavioral data analysis

We used *R* 4.0.2 (R Core Team, 2020) for running analysis of variance (ANOVA; e*z*; Lawrence, 2016), and for data visualization (*ggplot2*; Wickham, 2016). Participants with mean accuracy and mean response times (RTs) 2.5 *Standard Deviations* (*SD*) away from the group mean, were excluded from later analyses. For the remaining participants, accuracy and RTs were averaged by condition and analyzed with repeated-measures ANOVAs. Pairwise comparisons between critical conditions were performed with *t*-tests. Significance tests were two-tailed, unless *a priori* hypotheses justified one-tailed tests; this was the case for the search asymmetry between interacting non-interacting dyads. The same analytic approach was used in all experiments. All data and scripts for analysis are available on https://osf.io/vs7m6/.

Eye-tracking data analysis

The purpose of eye tracking was to assure that participants had their eyes in central fixation when the trial began, and therefore that our manipulation of the target eccentricity (central *vs.* peripheral) was effective. A trial began automatically when the participant fixated the cross. We also measured how long during a trial the participants fixated the central location, by computing central dwell times (*i.e.*, the proportion of looking time on the center of arrays, computed as the number of eye-tracking samples recorded on central locations, divided by the total number of eye-tracking samples) by participant and condition. Other measures such as dwell times on target (proportion of looking time on the target's side), number of first fixations on targets, and mean onset times of first fixations (first fixation time-to-onset) were also analyzed.

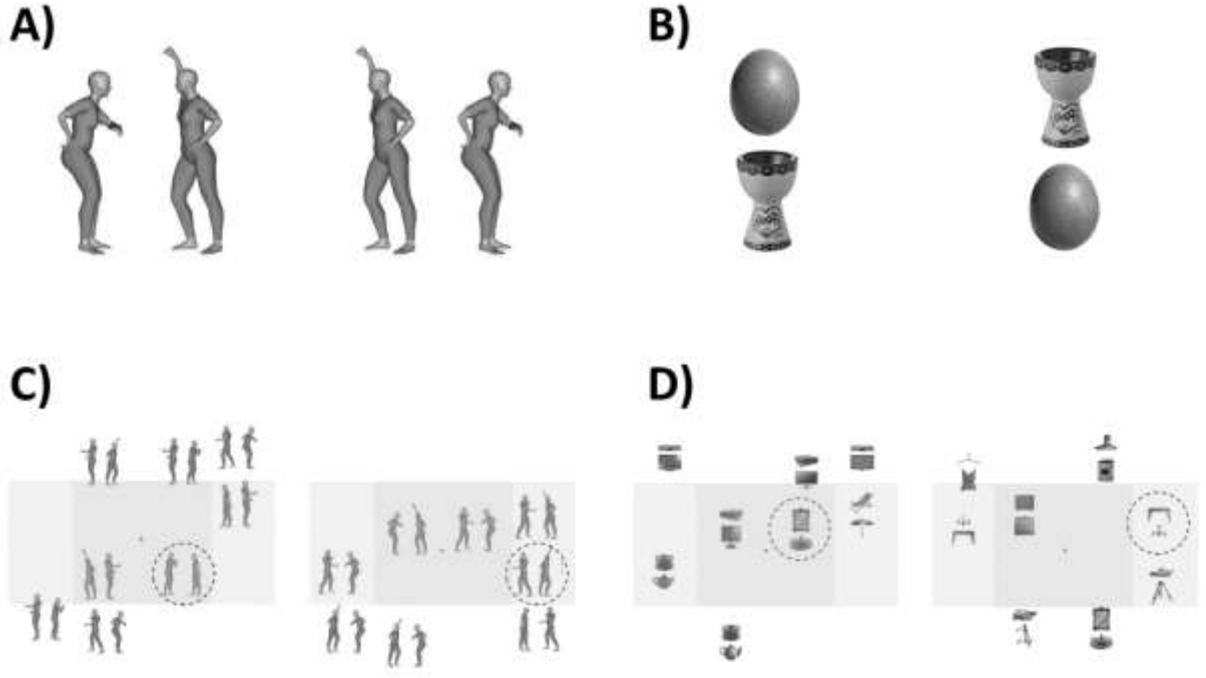

Figure 1. Stimuli of Experiments 1-4. A) Examples of interaction and non-interacting body dyads used in Experiments 1-4. **B)** Examples of functionally interacting and non-interacting object pairs used in Experiments 4. **C)** Examples of body-dyad arrays used in Experiments 1-4. Left: condition with an interacting dyad (target) among non-interacting dyads (distractors); right: condition with a non-interacting dyad (target) among interacting dyads (distractors). **D)** Examples of object-pair arrays used in Experiment 4. Left: condition with an interacting pair (target) among non-interacting pairs (distractors); right: condition with a non-interacting pair (target) among interacting pairs (distractors). Distractors could appear at any of sixteen possible locations. The target could appear at one of the eight locations highlighted with grey rectangle: four around central fixations (central locations, darker grey) and four, next to the edges of the arrays (peripheral locations, lighter grey). Targets are indicated by black circles. Neither the rectangles nor the circles were shown in the experiments.

Results

One participant had a mean accuracy 2.5 SD below the group mean and was excluded from further analysis. All other participants had mean RTs within 2.5 SD from the group mean. Respectively, seven and two trials were missed for two participants due to a technical failure of the eye-tracker. These two participants were however included in the analysis. Accuracy and RTs were analyzed in 2 (target configuration: interacting, non-interacting) × 2 (target eccentricity: central, peripheral) repeated-measures ANOVAs.

Accuracy. Analyzing accuracy (Fig. 2) showed a significant interaction between target configuration and eccentricity, *F*(1, 22) = 5.87, *p* = .024, η_p^2 = 0.21, with no main effect of configuration, *F*(1, 22) = 0.17, *p* = .687, η_p^2 = 0.01, and no main effect of eccentricity, *F*(1, 22) = 0.97, *p* = .336, η_p^2 = 0.05. Pairwise comparisons showed a search asymmetry between interacting and non-interacting targets at central locations, *t*(22) = 1.81, *p* = .042, *d* = 0.38, where interacting targets were found significantly better than non-interacting targets ($M_{interacting}$ = 0.84, *SD* = 0.11; $M_{non\text{-}interacting}$ = 0.81, *SD* = 0.11). The asymmetry tended to reverse with targets at peripheral locations, *t*(22) = -1.66, *p* = .056, *d* = -0.35, where accuracy was higher for non-interacting targets (*M* = 0.83, *SD* = 0.09) than interacting targets (*M* = 0.80, *SD* = 0.09). Moreover, interacting-dyad targets were more likely to be detected in central (*vs.* peripheral) locations, *t*(22) = 2.07, *p* = .050, *d* = 0.43, while there was no effect of eccentricity for non-interacting targets, *t*(22) = -1.15, *p* = .262, *d* = -0.24.

RTs. There was a significant effect of eccentricity, *F*(1, 22) = 7.52, *p* = .012, η_p^2 = 0.42, as participants were faster with targets at central than peripheral locations (M_{center}= 1267, *SD* = 266; $M_{periphery}$ = 1337, *SD* = 249). There was no main effect of configuration, *F*(1, 22) = 0.25, *p* = .625, η_p^2 = 0.06, and no interaction *F*(1, 22) = 0.67, *p* = .421, η_p^2 = 0.03.

Eye-tracking results. A trial began when the participant fixated the central fixation cross. Eye-tracking data analysis showed that the participants' eyes remained in the central area for most of the trial duration, with a mean proportion of central (vs. peripheral) dwell time of 0.74 (SD = 0.07). A repeated-measures ANOVA on central dwell times, with a 2 (target configuration: interacting, non-interacting) × 2 (target eccentricity: central, peripheral) design showed an effect of eccentricity, F(1, 22) = 388.56, p < .001, η_p^2 = 0.96, as participants' look departed from central fixation more often when the target was at the periphery (M = 0.67, SD = 0.07) than in the center (M = 0.80, SD = 0.08). The effect of configuration**,** F(1, 22) = 1.95, p = .176, η_p^2 = 0.42, and the interaction, F(1, 22) = 0.06, p = .814, η_p^2 = 0.00, were not significant. The analyses of dwell times on target, number of first fixations on targets, and mean onset times of first fixations showed no effects (see Supplementary material 1), meaning that the above effects on accuracy and RTs were independent from overt eye movements.

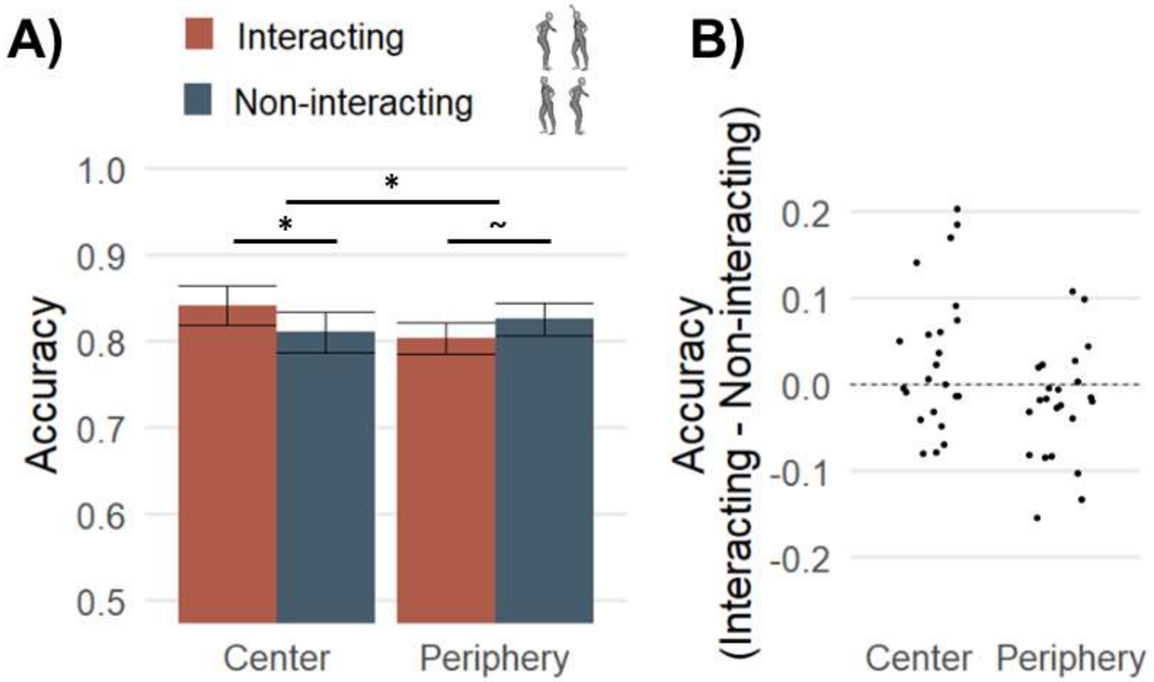

Figure 2. Results of Experiment 1. (A) Mean Accuracy as a function of target configuration (interacting/non-interacting) and target eccentricity (center/periphery). Bar plots represent the mean group accuracy with interacting dyads and non-interacting dyads; error bars are standard errors of the mean. * denote significant effects ($p < 0.05$); ~ denote trends ($p < .10$). **(B) Individual mean accuracy differences between interacting and non-interacting dyads**. Positive values indicate higher accuracy with interacting dyads, negative values, higher accuracy with non-interacting dyads; dots indicate individual participants.

Summary. Consistent with previous reports (Papeo et al., 2019), accuracy rates were more sensitive than RTs to experimental manipulations in the current task. Participants were more likely to correctly report an interacting dyad (target) among non-interacting dyads (distractors), when the target appeared around central fixation than at the periphery. However, the lack of search asymmetry at the periphery does not mean that participants did not detect the target at the periphery: performance with targets at peripheral locations was well above chance ($M = 0.81$, $SD = 0.08$, $t(22) = 17.90$, $p < .001$, $d = 3.73$) and participants gazed away from central fixation more often when the target was at a peripheral location. These results suggest that the asymmetry, with the advantage for interacting dyads, only emerged when the target appeared at the attended central location. However, when the task required searching through the array (*i.e.*, when the target was at peripheral locations outside fixation), the effect tended to reverse, as non-interacting targets were reported more accurately than interacting target.

Experiment 2

Experiment 1 showed an advantage for interacting over non-interacting targets in the center of array, but not at the periphery. Experiment 2 sought to replicate the results of Experiment 1 with two changes. First, Experiment 2 was carried out online, without eye-tracking. Second, we varied the set size, including arrays of both four and eight dyads (or eight and 16 bodies). The latter manipulation was introduced to test to what extent performance was affected by the number of distractors, taking the effect of set size (*i.e.*, slower RTs for the larger set size) as an indication of serial search through the array (Treisman & Gelade, 1980).

Methods

Participants

Experiment 2 was implemented on Testable.org (www.testable.org/) (Rezlescu et al., 2020), a platform for stimulus presentation and response recording, with built-in procedures for taking care of differences in screen resolution among different private devices. Twenty-four healthy participants (4 females; age: *M* = 24 years, *SD* = 4.19) were recruited as paid volunteers. Participants were included provided that they had a track record of “correct participants” in 90% of the online studies in Testable.org, and gave informed consent.

Stimuli and procedures

Due to limited online storage capacity of the online platform, we created only two lists of 400 search arrays. Participants were randomly assigned to one of the two lists. In each list, half of the arrays contained an interacting target among three (100 trials) or seven (100 trials) non-interacting distractors; the other half contained a non-interacting target among three (100 trials) or seven (100 trials) interacting distractors. Targets appeared randomly at central (50% trials) or peripheral locations.

Participants accessed the experiment through a link shared on Testable.org. Before the experiment, they were invited to follow the instructions to calibrate the size of the display, in order to ensure that the image size was similar across different monitors. Next, participants were asked to set their room in a dim light, install the computer on a stable table, sit on a stable seat, align their eyes to the center of the computer’s screen at a distance of 60cm (arm length), and turn off the sound. Task instructions were identical to Experiment 1, except that here participants were asked to use the “e” key or the “o” key, to respond “left” or “right”, respectively. Familiarization, stimulus presentation, and trial structure were identical to Experiment 1.

Results

All participants had mean accuracy and RTs within 2.5 *SD* from the group average and were included in following analyses. Mean accuracy and RTs were analyzed in 2 (target configuration: interacting, non-interacting) × 2 (target eccentricity: central, peripheral) × 2 (set size: set 4, set 8) repeated-measures ANOVAs.

Accuracy (Fig. 3). We found a significant effect of set size, $F(1, 23) = 88.58$, $p < .001$, $\eta_p^2 = 0.95$, a significant interaction between target configuration and eccentricity, $F(1, 23) = 8.04$, $p = .009$, $\eta_p^2 = 0.48$, and a significant interaction between target configuration, target eccentricity and set size, $F(1, 23) = 11.62$, $p = .002$, $\eta_p^2 = 0.34$. Other main effects and interactions were not significant (configuration: $F(1, 23) = 0.28$, $p = .600$, $\eta_p^2 = 0.03$; eccentricity $F(1, 23) = 0.66$, $p = .425$, $\eta_p^2 = 0.07$; configuration x set size $F(1, 23) = 0.44$, $p = .513$, $\eta_p^2 = 0.04$; eccentricity x set size $F(1, 23) = 3.15$, $p = .089$, $\eta_p^2 = 0.23$).

Effect of eccentricity in the search for interacting vs. non-interacting targets. To understand the three-way interaction, we ran two separate ANOVAs for the two different set size conditions, which showed that results of Experiment 1 were fully replicated in Experiment 2. In particular, consistent with Experiment 1, the critical target configuration by eccentricity interaction was significant with set size of eight, $F(1, 23) = 13.11$, $p = .001$, $\eta_p^2 = 0.36$ (effect of configuration: $F(1, 23) = 0.42$, $p = .525$, $\eta_p^2 = 0.03$; effect of eccentricity $F(1, 23) = 2.15$, $p = .156$, $\eta_p^2 = 0.12$), revealing a search asymmetry in favor of interacting targets with targets at central locations

($M_{interacting}$ = 0.87, *SD* = 0.07; $M_{non\text{-}interacting}$ = 0.83, *SD* = 0.09; *t*(23) = 2.85, *p* = .004, *d* = 0.58), but not with targets at peripheral locations, where, again, an opposite trend was observed: better performance with non-interacting, than with interacting targets ($M_{interacting}$ = 0.81, *SD* = 0.09, $M_{non\text{-}interacting}$ = 0.85, *SD* = 0.07; *t*(23) = -1.63, *p* = .059, *d* = -0.33). Moreover, interacting targets were detected better at the center than at the periphery, *t*(23) = 3.63, *p* = .001, *d* = 0.74, but this was not the case for non-interacting targets, *t*(23) = -1.11, *p* = .278, *d* = -0.23. The target configuration by eccentricity interaction was not significant with set size of four, *F*(1, 23) = 0.63, *p* = .435, η_p^2 = 0.03 (effect of configuration: *F*(1, 23) = 0.02, *p* = .894, η_p^2 = 0.00; eccentricity: *F*(1, 23) = 0.67, *p* = .421, η_p^2 = 0.03).

Effect of set size in the search for interacting vs. non-interacting targets. We investigated the effect of set size in the search for interacting *vs.* non-interacting targets in two separate ANOVAs with factors target eccentricity (central, peripheral) and set size (set 4, set 8). Results showed a significant interaction for interacting targets (*F*(1, 23) = 14.01, *p* = .001, η_p^2 = 0.38; effect of eccentricity: *F*(1, 23) = 7.73, *p* = .011, η_p^2 = 0.37; effect of set size: *F*(1, 23) = 43.07, *p* < .001, η_p^2 = 0.87), showing that the effect of set size was significantly larger in the search for interacting targets at the periphery, *t*(23) = -7.02, *p* < .001, *d* = -1.43, compared to the search for interacting targets at central locations, *t*(23) = -4.44, *p* < .001, *d* = -0.91. With non-interacting targets, there was only a main effect of set size, *F*(1, 23) = 93.24, *p* < .001, η_p^2 = 0.85, showing that performance was better with the smaller set size arrays, regardless of whether the target was at the center of the periphery. There was no effect of eccentricity, *F*(1, 23) = 1.78, *p* = .195, η_p^2 = 0.11, or interaction, *F*(1, 23) = 0.16, *p* = .694, η_p^2 = 0.01.

RTs. We only found an effect of set size, *F*(1, 23) = 17.40, *p* < .001, η_p^2 = 0.30, showing that performance was faster with set size of four than eight. All other effects and interactions were not significant (configuration: *F*(1, 23) = 0.00, *p* = .974, η_p^2 = 0.00; eccentricity: *F*(1, 23) = 0.01, *p* = .915, η_p^2 = 0.00; configuration x eccentricity: *F*(1, 23) = 0.98, *p* = .333, η_p^2 = 0.02; configuration x set size: *F*(1, 23) = 0.42, *p* = .524, η_p^2 = 0.01; eccentricity x set size: *F*(1, 23) = 1.15, *p* = .295, η_p^2 = 0.05; configuration x eccentricity x set size: *F*(1, 23) = 1.27, *p* = .271, η_p^2 = 0.05).

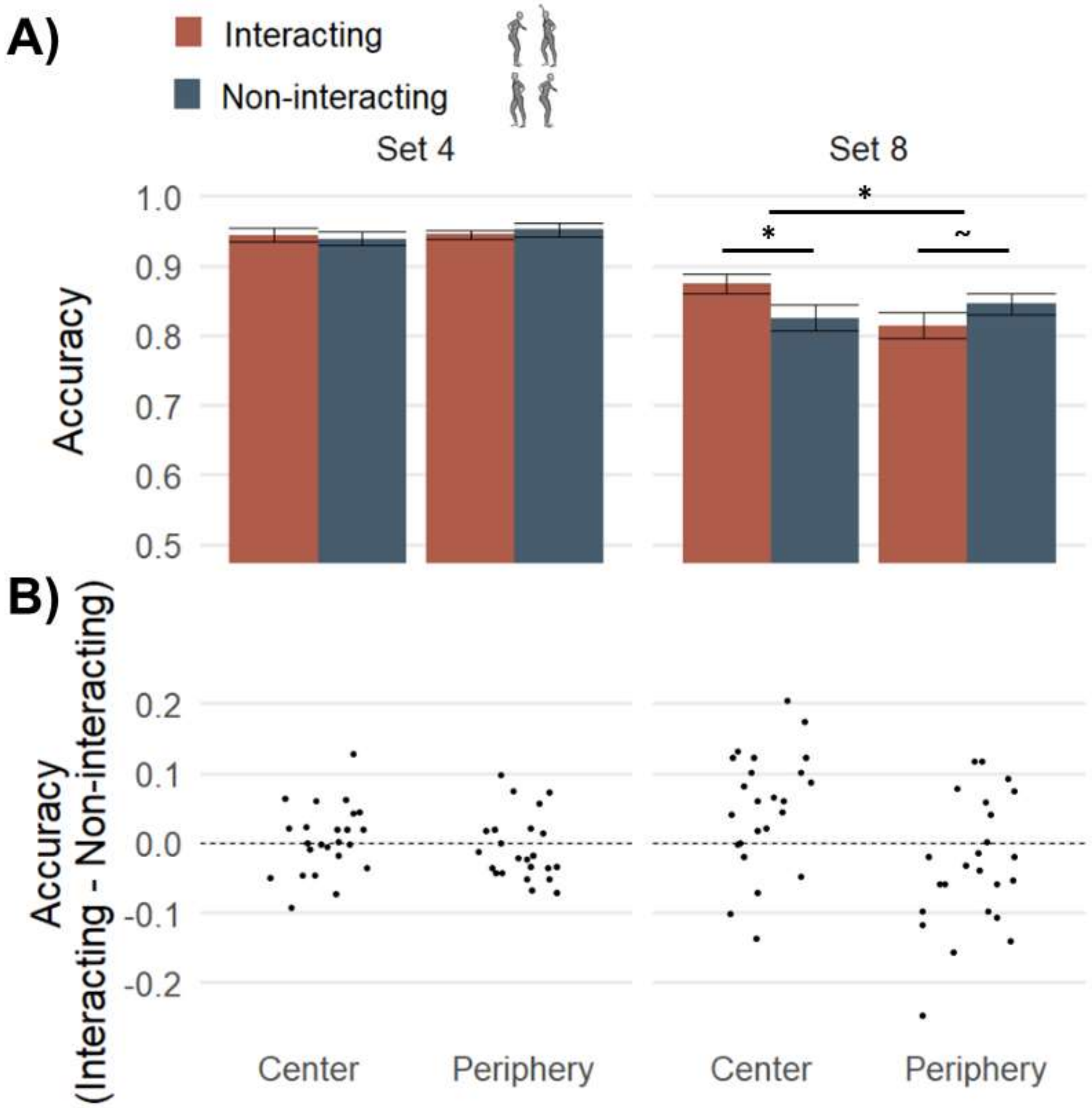

Figure 3. Results of Experiment 2. (A) Mean Accuracy as a function of target configuration (interacting/non-interacting), target eccentricity (center/periphery) and set size (four/eight dyads). Bar plots represent the mean group accuracy with interacting and non-interacting dyads; error bars are standard errors from the mean. * denote significant effects ($p < 0.05$); ~ denote trends ($p < .10$). **(B) Individual mean accuracy differences between interacting and non-interacting dyads.** Positive values indicate higher accuracy with interacting dyads, negative values higher accuracy with non-interacting dyads, dots indicate individual participants.

Summary. Accuracy results with set size of eight fully replicated the results of Experiment 1, showing a search asymmetry in favor of interacting dyads at the center, and a trend for an advantage for non-interacting targets at the periphery. Moreover, the search for interacting targets was less affected by the number of distractors (set size) at the center than at the periphery, in line with the hypothesis of a stronger recruitment of attention by an interacting target in the center *versus* greater reliance on serial search through the distractors with the target at the periphery. The same accuracy pattern was not found with set size of four, where performance approached ceiling, thus reducing the sensitivity to detect differences across conditions.

RT results only showed a general effect of set size (faster performance with set size of four than eight) but were not sensitive to other variations across conditions. In the current study, we opted for short stimulus duration as we were primarily interested in addressing the search advantage related to spontaneous attentional capture by the target. Different task conditions (*e.g.*, unlimited stimulus presentation times) may help to highlight effects in RTs, which is necessary to evaluate the effects of set size on visual search using search slopes.

Experiment 3

Experiments 1-2 showed that the search advantage for interacting dyads emerged with targets presented at the attended (central) spatial location. In addition, Experiments 1-2 showed that the pattern tended to reverse towards an advantage for non-interacting dyads, with targets at the periphery, a condition that increases the demand for a search through the array, beyond the attended location. Here, we asked whether this reversal of effects would become statistically more reliable when extending the stimulus duration to allow more time to explore the periphery of the visual field.

Methods

Participants

Twenty-four new healthy participants (7 females; age: M = 26 years, SD = 4.96) were recruited as paid volunteers. Participants were included if they had a track record of “correct participant” in 90% of the online studies in Testable.org, and provided informed consent.

Procedures

Stimuli, familiarization, instructions and procedures were identical to Experiment 2, except for two details. First, stimulus duration was increased by 50%, for a total of 1200 ms per stimulus. Second, the set size was kept constant and corresponded to eight dyads. Each participant saw 400 arrays featuring one interacting target among seven non-interacting distractors (200 trials), or one non-interacting target among seven interacting distractors (200 trials). Targets appeared randomly in central (50% trials) or peripheral locations.

Results

We excluded data from two participants who had a mean accuracy 2.5 *SD* below the group mean and mean RTs more than 2.5 *SD* away from the group mean. Mean accuracy rates and RTs of the remaining participants were analyzed in 2 (target configuration: interacting, non-interacting) × 2 (target eccentricity: central, peripheral) repeated-measures ANOVAs.

Accuracy (Fig. 4). We found an interaction between target configuration and eccentricity, $F(1, 21) = 7.44$, $p = .013$, $\eta_p^2 = 0.26$, a main effect of eccentricity, $F(1, 21) = 5.79$, $p = .025$, $\eta_p^2 = 0.32$, but no effect of configuration, $F(1, 21) = 0.01$, $p = .938$, $\eta_p^2 = 0.00$. Pairwise comparisons showed a significant search asymmetry in favor of interacting targets at central locations ($M_{interacting} = 0.90$, $SD = 0.07$; $M_{non\text{-}interacting} = 0.87$, $SD = 0.06$; $t(21) = 1.82$, $p = .041$, $d = 0.39$), and the reversed asymmetry at peripheral locations, $t(21) = -1.87$, $p = .038$, $d = -0.40$, where participants were more accurate for non-interacting dyads ($M = 0.86$, $SD = 0.07$) than interacting dyads ($M = 0.83$, $SD = 0.08$). Moreover, interacting targets were found better at the center than at the periphery, $t(21) = 3.28$, $p = .004$, $d = 0.70$. This effect was not found for not non-interacting targets, $t(21) = 0.26$, $p = .797$, $d = 0.06$.

RTs. We found a significant main effect of eccentricity, $F(1, 21) = 17.08$, $p < .001$, $\eta_p^2 = 0.30$, as participants were faster with central ($M = 2001$, $SD = 279$) than peripheral targets ($M = 2061$, $SD = 282$). There was no main effect of configuration, $F(1, 21) = 2.24$, $p = .150$, $\eta_p^2 = 0.38$, and no interaction, $F(1, 21) = 0.09$, $p = .769$, $\eta_p^2 = 0.00$.

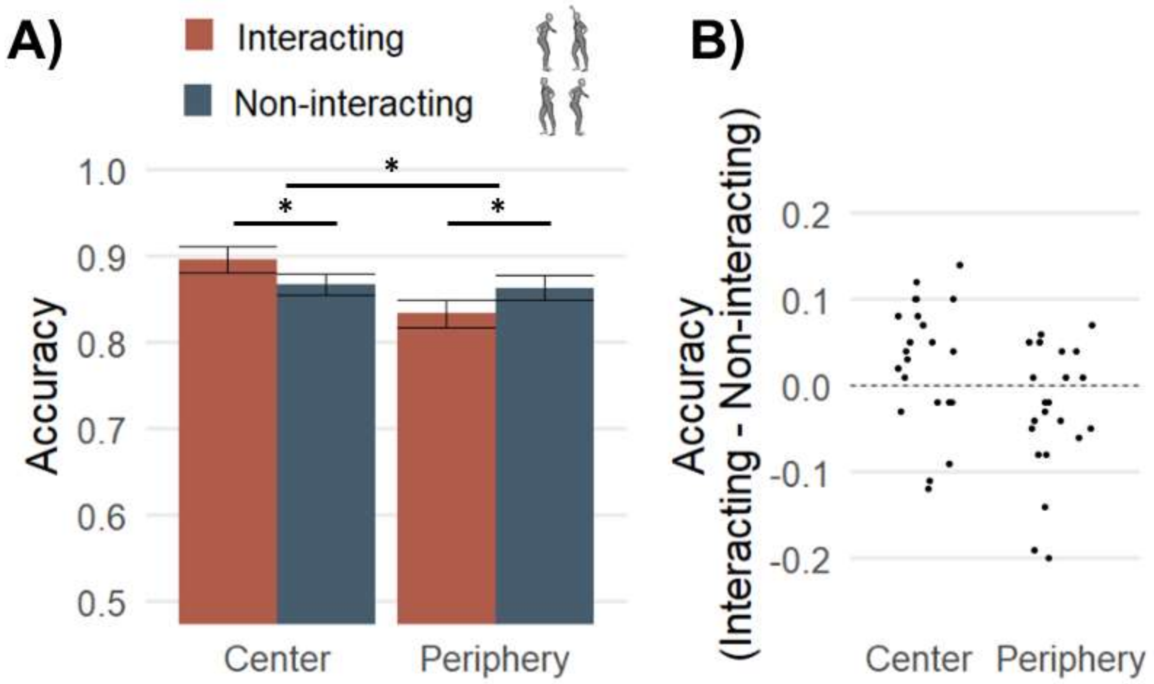

Figure 4. Results of Experiment 3. (A) Mean Accuracy as a function of target configuration (interacting/non-interacting) and target eccentricity (center/periphery). Bar plots represent the mean group accuracy with interacting and non-interacting dyads; error bars are standard errors from the mean. * denote significant effects ($p < 0.05$). **(B) Individual mean accuracy differences between interacting and non-interacting dyads.** Positive values indicate higher accuracy with interacting dyads, negative values higher accuracy with non-interacting dyads; dots indicate individual participants.

Summary. The longer stimulus presentation implemented in Experiment 3 did not change the search advantage for interacting targets at central locations: participants detected interacting dyads better than non-interacting dyads, when the target appeared at the attended central location. With longer stimulus presentation, however, the advantage for non-interacting targets at the periphery, which was a trend in Experiments 1-2, here became statistically reliable. This result indeed indicates that target presentation at peripheral locations induced serial search through the array and that this search benefited from a meaningful, structured configuration of the distractors. Altogether Experiments 1-3 suggest that the advantage for interacting dyads can be explained by fast and automatic perceptual mechanisms operating on the attended location, such as a perceptual enhancement of parts (*i.e.*, the interacting dyad) of a complex scene. While making the task overall more difficult (see main effect of eccentricity in Experiments 1-3), peripheral target presentation did not just abolish the above asymmetry, but reversed the effect: participants were more likely to detect non-interacting dyads than interacting dyads, suggesting a change in the underlying mechanism, from immediate attentional capture when a salient target (the interacting dyad) was in central vision, to more efficient serial search through arrays of distractors that could be processed more efficiently (the –grouped– interacting dyads). To assess the statistical significance of this reversal, the mean accuracy of participants from Experiments 1, 2 and 3 was pooled, and entered in a 2 (target configuration: interacting, non-interacting) × 2 (target eccentricity: central, peripheral) repeated-measures ANOVAs. This found a significant interaction between target configuration and eccentricity, $F(1, 68) = 26.29$, $p < .001$, $\eta_p^2 = 0.28$, a main effect of eccentricity, $F(1, 68) = 8.10$, $p = .006$, $\eta_p^2 = 0.14$, but no effect of configuration, $F(1, 68) = 0.38$, $p = .537$, $\eta_p^2 = 0.01$.

Experiment 4

Experiments 1-3 revealed a complex pattern of asymmetries in visual search for interacting or non-interacting dyads: interacting dyads were detected better in central vision and non-interacting dyads were detected better at the periphery. In Experiment 4, we tested whether the pattern found for interacting *vs.* non-interacting dyads in Experiments 1-3 generalized to object pairs appearing in their regular spatial and functional arrangement (hereafter: interacting pairs; e.g., a computer screen above a keyboard, a mirror above a sink, or a lamp above the table), compared with object pairs arranged in an irregular way (hereafter: non-interacting pairs; e.g., a computer screen below a keyboard, a mirror below a sink, or a lamp below the table).

Methods

Participants

A new group of twenty-four healthy participants (19 females; age $M = 22$, $SD = 2.83$) were recruited and tested in the lab. Participants were paid volunteers with normal or corrected-to-normal vision, no psychiatric history or current medication reported. They were enrolled after providing informed consent.

Stimuli and procedures

Search arrays were created from eleven pairs of everyday gray-scale objects used in previous studies (Kaiser et al., 2014). In the arrays, the pairs could appear in their typical vertical configuration for common usage (interacting pairs: *e.g.*, a lamp above a dining table, a mirror above a bathroom sink, or an air vent above a stove; Fig. 1B, left), or vertically swapped (non-interacting pairs: *e.g.*, a lamp below a table, a mirror below a bathroom sink, an air vent below a stove; Fig. 1B, right). For each single objects (*e.g.*, table), two different exemplars were included (table A and table B), resulting in four different exemplars for each pair (table A-lamp A, table B-lamp A, table B-lamp A, table B-lamp B), and a total of 44 functionally interacting and 44 non-interacting pairs. Arrays were generated following the same procedure described for body dyads, except for two differences. First, search arrays did not display more than one pair from the same type (*e.g.*, only one lamp-table pair per display). Second, the two halves of the arrays contained different pairs (*i.e.*, one half was not the mirror version of the other half, as in Experiments 1-3). This was done to prevent the target to be found because it corresponded to the only asymmetric part of the array. Search arrays with body dyads were modified relative to Experiment 1, to match these features of the object-pair arrays (only one repetition of the same dyad in each array and different dyads in the two halves of the array).

For each participant, 800 unique arrays were generated, 400 with body dyads and 400 with object pairs. Half of the arrays included a target among seven distractors; the other half included a target among nine distractors (Fig. 1D). Targets occurred in a central (50% trials) or at a peripheral location. Arrays with object pairs and arrays with body dyads were presented in two different blocks.

In the object-pair condition, in two separate blocks, participants were instructed to search for the only interacting pair among the non-interacting pairs (Fig. 1D, left), or for the only non-interacting pair among the interacting pairs (Fig. 1D, right). In the body-dyad conditions, in two separate blocks, participants were instructed to search for the only interacting dyad among the non-interacting dyad pairs, or for the only non-interacting dyad among the interacting dyads, as in previous experiments. The order of blocks was alternated across participants: the experiment started with either body-dyads or object-pairs, and within each type-condition, with either interacting or non-interacting targets. Before each block, participants were familiarized with the instructions and stimuli of each sub-block, in the same order, with 8 trials presenting 4 stimuli for each of the 2 experimental conditions. Arrays were displayed on a 17-in. CRT monitor (1024 × 768 pixel resolution, 85-Hz refresh rate) positioned 60 cm from the participant's eyes. Participants sat on a height-adjustable chair with their eyes aligned to the center of the screen. Stimulus presentation and response collection were controlled through the Psychophysics Toolbox extension of MATLAB (Brainard, 1997). The entire experiment lasted ~60 min.

Results

One participant with a mean accuracy rate 2.5 SD below the group mean was discarded. All other participants had mean RTs within 2.5 SD from the group mean and were included in analysis. Mean accuracy rates and RTs were analyzed in 2 (target configuration: interacting, non-interacting) × 2 (target eccentricity: central, peripheral) × 2 (set size: set 8, set 10) × 2 (target type: bodies, objects) repeated-measures ANOVAs.

Accuracy (Fig. 5). We found an effect of set size, $F(1, 22) = 27.12$, $p < .001$, $\eta_p^2 = 0.48$, as participants were more accurate with smaller set size arrays ($M_{eight} = 0.80$, $SD = 0.06$; $M_{ten} = 0.77$, $SD = 0.07$), an effect of target type, $F(1, 22) = 114.132$, $p < .001$, $\eta_p^2 = 0.93$, as participants were more accurate with bodies ($M = 0.84$, $SD = 0.07$) than objects ($M = 0.73$, $SD = 0.07$), and a significant interaction between target configuration, eccentricity and target type, $F(1, 22) = 5.71$, $p = .026$, $\eta_p^2 = 0.33$. Other effects and interactions were not significant (configuration: $F(1, 22) = 0.55$, $p = .467$, $\eta_p^2 = 0.04$; eccentricity: $F(1, 22) = 0.90$, $p = .353$, $\eta_p^2 = 0.07$; configuration x eccentricity: $F(1, 22) = 1.65$, $p = .213$, $\eta_p^2 = 0.13$; configuration x set size: $F(1, 22) = 0.69$, $p = .414$, $\eta_p^2 = 0.03$; configuration x type: $F(1, 22) = 2.04$, $p = .167$, $\eta_p^2 = 0.27$; eccentricity x set size: $F(1, 22) = 1.81$, $p = .193$, $\eta_p^2 = 0.06$; eccentricity x type: $F(1, 22) = 0.00$, $p > .999$, $\eta_p^2 = 0.00$; set size x type: $F(1, 22) = 0.75$, $p = .396$, $\eta_p^2 = 0.02$; configuration x eccentricity x set size: $F(1, 22) = 3.41$, $p = .078$, $\eta_p^2 = 0.09$; configuration x set size x type: $F(1, 22) = 0.13$, $p = .717$, $\eta_p^2 = 0.01$; eccentricity x set size x type: $F(1, 22) = 0.16$, $p = .695$, $\eta_p^2 = 0.01$; configuration x eccentricity x set size x type: $F(1, 22) = 0.02$, $p = .900$, $\eta_p^2 = 0.00$).

To understand the interaction, we computed two 2 (target configuration: interacting, non-interacting) × 2 (target eccentricity: central, peripheral) repeated-measures ANOVAs for body- and object-trials, separately. For bodies, we found a significant interaction between target configuration and eccentricity, $F(1, 22) = 5.52$, $p = .028$, $\eta_p^2 = 0.20$, with no main effects of configuration, $F(1, 22) = 0.50$, $p = .488$, $\eta_p^2 = 0.03$, or eccentricity, $F(1, 22) = 0.47$, $p = .499$, $\eta_p^2 = 0.02$. Like in Experiments 1-3, interacting targets were detected better at the center than at the periphery, *t*(22) = 2.21, *p* = .038, *d* = 0.46, while this was not the case for non-interacting targets, *t*(22) = -1.32, *p* = .200, *d* = -0.28. Moreover, consistent with Experiments 1-3, there was a trend for a search asymmetry in favor of interacting dyads, with targets in central locations ($M_{interacting}$ = 0.86, *SD* = 0.10; $M_{non\text{-}interacting}$ = 0.82, *SD* = 0.08; *t*(22) = 1.68, *p* = .054, *d* = 0.35), but not with targets at the periphery ($M_{interacting}$ = 0.82, *SD* = 0.08; $M_{non\text{-}interacting}$ = 0.84, *SD* = 0.09; *t*(22) = -1.27, *p* = .108, *d* = -0.27). Numerically, however, the search for the target at the periphery matched the effect in Experiments 1: better search for non-interacting than interacting targets. A weaker effect here could reflect design differences between the previous experiments and the current one, which involved modified search arrays and body-trials interspersed with object-trials in the same session.

For object pairs, the ANOVA only showed a trend for the effect of configuration, *F*(1, 22) = 3.49, *p* = .075 η_p^2 = 0.18: regardless the location, non-interacting targets tended to be detected more successfully than interacting targets. There was no effect of eccentricity, *F*(1, 22) = 0.88, *p* = .358, η_p^2 = 0.03, or interaction, *F*(1, 22) = 0.75, *p* = .395, η_p^2 = 0.03.

RTs. RTs showed effects of eccentricity, *F*(1, 22) = 11.89, *p* = .002, η_p^2 = 0.62, target type, *F*(1, 22) = 35.52, *p* < .001, η_p^2 = 0.99, and set size *F*(1, 22) = 43.32, *p* < .001, η_p^2 = 0.77. The interaction between set size and target type was significant, *F*(1, 22) = 6.26, *p* = .020, η_p^2 = 0.34, reflecting a larger effect of set size (faster responses with smaller than larger sets) for body-trials, *t*(22) = -6.45, *p* < .001, *d* = -1.35, than objects *t*(22) = -2.73, *p* = .012, *d* = -0.57 (8 pairs: *M* = 1501, *SD* = 219; 10 pairs: *M* = 1535, *SD* = 218). Finally, there was a significant interaction between target configuration and eccentricity, *F*(1, 22) = 4.63, *p* = .043, η_p^2 = 0.21. This interaction showed that the effect of eccentricity (faster responses at central than peripheral locations) was larger for interacting bodies/objects, *t*(22) = -3.39, *p* = .003, *d* = -0.71, than for non-interacting bodies/objects *t*(22) = -2.27, *p* = .033, *d* = -0.47. Other effects and interactions were not significant (configuration: *F*(1, 22) = 0.86, *p* = .364, η_p^2 = 0.39; configuration x set size: *F*(1, 22) = 0.54, *p* = .469, η_p^2 = 0.04; configuration x type: *F*(1, 22) = 3.35, *p* = .081, η_p^2 = 0.58; eccentricity x set size: *F*(1, 22) = 0.02, *p* = .889, η_p^2 = 0.00; eccentricity x type: *F*(1, 22) = 0.55, *p* = .467, η_p^2 = 0.06; configuration x eccentricity x set size: *F*(1, 22) = 1.20, *p* = .286, η_p^2 = 0.11; configuration x eccentricity x type: *F*(1, 22) = 1.47, *p* = .238, η_p^2 = 0.10; configuration x set size x type: *F*(1, 22) = 0.47, *p* = .502, η_p^2 = 0.04; eccentricity x set size x type: *F*(1, 22) = 0.06, *p* = .809, η_p^2 = 0.00; configuration x eccentricity x set size x type: *F*(1, 22) = 1.08, *p* = .311, η_p^2 = 0.05).

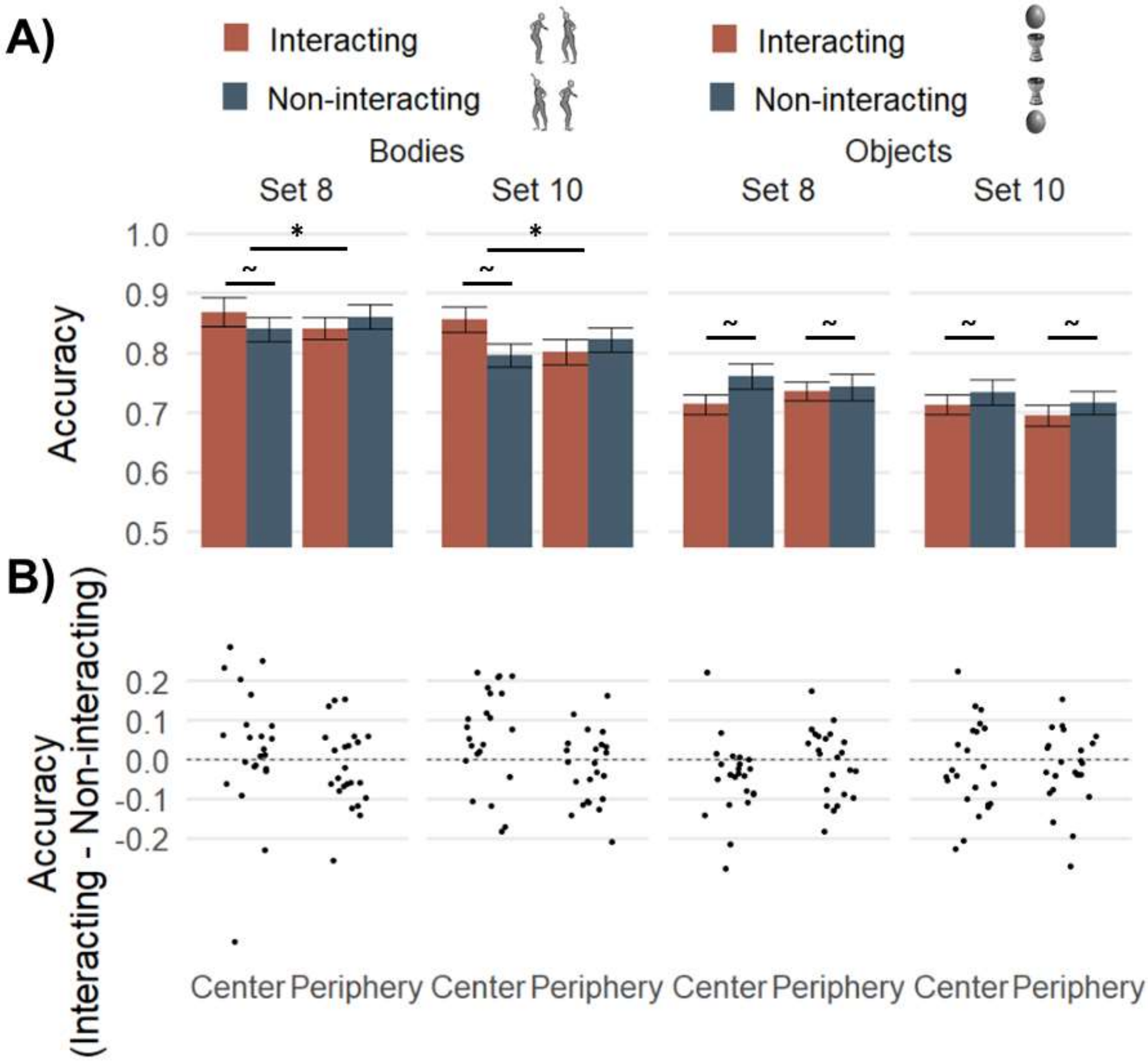

Figure 5. Results of Experiment 4. (A) Mean Accuracy as a function of target type, target configuration (interacting/non-interacting), target eccentricity (center/periphery) and set size. Bar plots represent the mean group accuracy with interacting dyads (light brown) and non-interacting dyads (dark blue); error bars are standard errors from the mean. * denote significant effects (p < 0.05). ~ denote trends (*p* < .10). **(B) Individual mean accuracy differences between interacting and non-interacting dyads.** Positive values indicate higher accuracy with interacting dyads, negative values higher accuracy with non-interacting dyads, dots indicate individual participants.

Summary. Experiment 4 showed different patterns of performance in visual search through body dyads and object pairs. Participants were generally more accurate and responded faster with bodies than objects and in smaller than larger sets. Set size had a stronger influence on search time for bodies than objects but did not interact with the target configuration. More importantly, consistent with the previous experiments, the search advantage (in accuracy rates) for interacting dyads was only found when targets were in central locations. With targets at peripheral locations, performance was qualitatively better in the search for non-interacting (*vs.* interacting) targets. A similar effect was found with object pairs regardless of the target eccentricity: whether at the center or at the periphery, non-interacting object pairs tended to be detected more frequently than interacting pairs. Thus, the multifaceted effect of social interaction does not extend to non-social relations. Object sets in meaningful (*e.g.*, functionally relevant) spatial relations are generally grouped and thus easier to reject, but they do not possess the same ability to capture attention when shown at the center.

General discussion

The current study addressed whether and how spatially defined higher-level relations (*e.g.*, a social interaction implied by *facingness*) affect visual search. In particular, we investigated *a)* how people searched for interacting (face-to-face) bodies in a crowd of non-interacting (back-to-back) dyads, and *vice versa*; *b)* how the spatial location of the target in the visual field (*i.e.*, its eccentricity) affected search; and *c)* whether the pattern of search performance with body dyads generalized to other pairs instantiating another type of high-level relation (*i.e.*, objects in functional configurations for common usage).

Results reveal a complex pattern of search asymmetries. Interacting dyads among non-interacting dyads were detected better than non-interacting dyads among interacting dyads. This advantage for interacting dyads was only found when the target appeared in a central location, that is, in a location that was in the participant's focus of attention. When the target appeared at more peripheral locations, non-interacting dyads were detected better than interacting dyads. Thus, peripheral target location did not just abolish the asymmetry in favor of interacting dyads but reversed the effect. The latter effect generalized to the search for object pairs, independently of target location: whether presented in central or peripheral locations, non-interacting objects were detected better than interacting objects.

The advantage for interacting body dyads in central vision replicates the visual search asymmetry reported in Papeo *et al.* (2019), who showed that, with fast stimulus presentation, interacting targets among non-interacting distractors were detected better than non-interacting targets among interacting distractors. Adding to those findings, the current results specify the boundaries of the asymmetry, showing that attentional capture by interacting dyads only happens with target presentation at the attended central location.

This result show that *facingness,* a reliable cue of social interaction, makes two people particularly salient at the attended spatial location (Papeo et al., 2017; Papeo et al., 2019; see also Vestner et al., 2019; Skripkauskaite et al., 2022). This effect may be promoted by the perceptual enhancement of interacting dyads suggested by neuroimaging findings. In effect, fMRI research using classification analyses has shown that facing bodies have a stronger representation in visual cortex, relative to the same bodies presented in non-facing configurations (Abassi & Papeo, 2020; Bellot et al., 2021). This neural effect could be linked to behavioral effects showing that body postures and movements seen in an interacting context are discriminated better (Bellot et al., 2021; Neri et al., 2006) and remembered better (Ding et al., 2017; Paparella & Papeo, 2022; Vestner et al., 2019) than the same stimuli presented as unrelated or in isolation. In sum, interacting dyads capture attention because their relative positioning makes them more salient, and therefore more visible, relative to unrelated bodies.

Why isn't that the case for facing dyads at peripheral locations? Interacting and non-interacting bodies are more difficult to discriminate at the periphery of the search arrays due to the effects of eccentricity (*i.e.*, decreased spatial resolution with increasing degrees of eccentricity; Carrasco & Frieder, 1997; De Valois & De Valois, 1988) and crowding (Bouma, 1970). Visual crowding is the phenomenon in which an object in peripheral vision can be recognized in isolation but not when flanked by other objects, especially when target and flankers are visually similar, as it is the case for our body dyads (Whitney & Levi, 2011). Thus, when the target is not in central vision, interacting and non-interacting dyads cannot be readily discriminated, and the participant needs to start a search through the array. As our results show, this search is easier when the majority of distractors are interacting dyads and more difficult when they are non-interacting dyads. This effect is predicted by possible differences in the way interacting and non-interacting distractors are visually represented. In particular, the facilitatory effect of related distractors in visual search adds up to other behavioral and neural effects suggesting that the spatial positioning of objects according to meaningful relations (*e.g.*, real-world regularities) triggers grouping of multiple objects into a perceptual unit (Kaiser et al., 2019). Grouping in visual search would effectively reduce the number of distractors to check and reject, thus increasing search efficiency (Kaiser et al., 2014). In parallel, and in line with this, growing literature shows that *facingness*, as a cue of interaction, triggers grouping of two people into a unitary perceptual structure (Abassi & Papeo, 2022; Adibpour et al., 2021; Papeo & Abassi, 2019; Vestner et al., 2019).

Overall, our results show that spatial relations that imply interaction between people or objects affect visual search. Visual search benefits from visual relational information by treating related items as single attentional units, thus reducing the number of items to process in an array. This mechanism is common to objects and people, or social and non-social relations. At the same time, interacting dyads capture attention when close to the initial attentional focus, while objects do not. This suggests that there are shared but also different mechanisms for processing of social and non-social visual relational information. Differences can reflect visual and semantic dissimilarities between object categories. For example, here, bodies were all visually very similar (in fact, the very same body was shown in different postures across all dyads); whereas objects belonged to various, visually different, categories. Moreover, while relations between bodies unfolded along the horizontal axis, object pairs were organized vertically. Body dyads and object pairs might also entail different levels of representation. That is, all facing dyads might trigger a general representation of interaction, while each interacting object pair might specify a relation, different from the others (lamp above table could be “dining area”, monitor above keyboard could be “computer” and so on), which would make object pairs easier to separate than body dyads. Difference between body dyads and object pairs may also reflect the use that we, as humans, make of relational information, and/or its relevance in the ecological setting. Detecting and recognizing social interactions in the wild is crucial for survival, and as a primary source of information for social learning. Stimuli that are reliably associated with social interaction (*e.g.*, face-to-face body positioning) might have been prioritized in attention/perception throughout ontogeny and phylogeny (see New et al., 2007, for a perspective on evolutionary constraints on visual attention). In contrast, spotting a group of regularly positioned objects is not typically associated with such behavioral rewards. In navigating the environment, the visual system could use a strategy, where the regular, meaningful, and familiar configurations of objects are efficiently discarded to focus on the important –socially and biologically relevant– information, such as conspecifics, other animals, and their interactions.

In this spirit, the current results support the idea of a special status for interacting bodies in visual attention (see Papeo, 2020). However, it remains possible that other categories of stimuli or relations benefit from a similar advantage. The work of Vestner et al. (2020; 2021; 2022) suggests that an attentional capture similar to the one observed for interacting bodies could be observed for pairs of facing objects whose orientation (leftward or rightward) provides a strong directional cue (*e.g.*, cars and cameras). A direct comparison with our results however is limited by significant differences in the paradigms. Vestner *et al.* presented arrays of four stimuli around the central fixation (alike our “central” condition) for unlimited time, and did not test for visual search asymmetries: facing and non-facing pairs did not swap role in two conditions, as in classic search asymmetry paradigms (condition A: facing is the target, non-facing is the distractor; condition B: non-facing is the target, facing is the distractor), but were only used as targets among other distractors. Future studies should further extend the present comparison of socially interacting bodies and functionally interacting objects to other classes of stimuli and relations to clarify the types of stimuli/relations that are processed analogously to visual illustrations of social interaction (i.e., facing dyads).

To summarize, here we elicited two apparently conflicting effects reported in the literature in a single design, showing that interacting dyads capture attention more strongly than non-interacting dyads, but are also easier to reject as distractors. The new results reported here show how the same stimuli (interacting dyads) can give rise to different effects in visual search (attentional capture or more efficient search) based on target eccentricity (central/peripheral), determined by how much search thought the distractors is required. Meaningful relations between individual items structure the array in a way that reduces the number of units to process, facilitating the search for a target. This mechanism applies to social dyads as well as to non-social object pairs. The presentation of the target at the attended central location breaks this effect, but only when the target is a social dyad and only when the two members of the dyad are face-to-face, as if interacting. More generally, we showed how new units of perception emerge from higher-level relations such as social interaction or functional association, which are not explained by low-level visual properties of the stimuli (*e.g.*, proximity, similarity, contours, continuity), and yet bind visual entities together, impacting the way in which individuals parse the visual world.

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