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 this 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 a peripheral location. 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, the advantage disappeared, or even tended to reverse in favor of non-interacting dyads. In Experiments 4-5, we asked whether the search asymmetry generalized to object pairs whose spatial relations did or did not form a functionally interacting set (a computer screen *above* a keyboard *vs.* a computer screen *below* a keyboard). We found no advantage for interacting over non-interacting sets either in central or peripheral locations for objects, but, if anything, evidence for the opposite effect. Thus, the effect of relational information on visual search is contingent on both stimulus category and attentional focus: the presentation of social interaction –but not of non-social interaction– at the attended (central) location readily captures an individual's attention.

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

Public significance statement

A tradition of research on how people search for a given target in the cluttered environment, has emphasized selection by spatial location, visual features or whole objects. Here, we ask how people search for other people in a crowded environment. We provide evidence that visual search can afford a fast appraisal of relations between individuals, prioritizing those who appear to be socially engaged: in a crowded array, people find more easily two individuals face-to-face than the same two seen back-to-back. This advantage for seemingly interacting human dyads is especially strong when they appear in the attended part of the visual field. Moreover, the advantage for interacting people does not generalize to pairs of objects in spatial relations that imply functional interactions: in an array of familiar, everyday objects, a computer screen *above* a keyboard forming a workstation is not found more efficiently than a computer screen *below* a keyboard.

Introduction

Each moment in the visual world is a cluttered scene, where structure emerges from spatial relations between things. Spatial relations can also indicate social relationship. Proximity and *facingness*, the mutual perceptual accessibility of two (or more) people, are reliable cues of social interaction, which individuals readily exploit to detect and decipher social events (Hall, 1966; Papeo, 2020; Quadflieg & Koldewyn, 2017; Zhou 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). One approach has relied on visual search asymmetries. Visual search asymmetries have been 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 make it more salient to visual attention than B (Treisman & Souther, 1985; Wolfe, 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 (hereafter: interacting target) among a set of back-to-back dyads (hereafter: non-interacting distractors), than a non-interacting target among a number of interacting dyads. Other results however revealed a different way in which interaction can affect attention: non-interacting targets can be found more efficiently than interacting targets, because interacting dyads can be easier to process and reject as distractors, relative to non-interacting dyads (Papeo et al., 2019; see also Kaiser et al., 2014; Kaiser et al., 2019; Papeo, 2020). Whether one effect (advantage for interacting target) or the other (advantage for non-interacting target) is observed may depend on the task conditions. For example, in previous studies (Papeo et al., 2019), the advantage for interacting targets was found when the target was presented in a subset of (central) locations, while the advantage for non-interacting targets was found when the target could appear at any location (central or more peripheral) of the array.

In sum, the results of Papeo et al. (2019) showed that visual search has rapid access to relations between bodies (see also Vestner et al., 2019). Those results also suggested that *where* interacting people are located in space critically affects *how* interactions influence attention. This aspect of the phenomenon has however not been further investigated.

Here we tested the visual search asymmetry for interacting *vs.* non-interacting targets; moreover, we systematically manipulated the location of the target in the array, by varying the target eccentricity (i.e., the distance of the target from central vision). If interacting bodies are more salient than non-interacting bodies, we should find an asymmetry in favor of interacting dyads. This effect may be especially visible with targets in central locations. In fact, when a target is already at the attended (central) location, performance emphasizes differences in the capacity of the targets to capture attention and/or to be accepted as target. With targets in peripheral locations, if interacting dyads are processed more efficiently, visual search for a target throughout the array should be more efficient in an array where the majority of dyads are interacting (Kaiser et al., 2014). As a result, we should observe an asymmetry in favor of non-interacting dyads. In sum, following up on previous research, we tested two possible –non mutually exclusive– ways in which a processing advantage of interacting dyads can affect visual search: by making them easier/faster to *process-and-accept* as targets and easier/faster to *process-and-reject* as distractors.

Furthermore, we investigated to what extent the effects of interacting/non-interacting dyads in visual search generalize to interactions between objects. To this end, we also tested participants in a visual search task with arrays of objects that could be arranged to form functional sets (interacting pairs: e.g., a computer screen above a keyboard, a mirror above a sink, or a lamp above a table) or not (non-interacting pairs: a computer screen below a keyboard, a mirror below a sink, or a lamp below a table). These kinds of stimuli have previously been used in visual search (Kaiser et al., 2015; Kaiser et al., 2019; Stein et al., 2015), showing that the search for a single-object target (e.g., a house) is facilitated when distractor-objects are arranged in functional sets, relative to when their canonical spatial relations are scrambled. No visual search asymmetry for functionally interacting *vs.* non-interacting object sets has been tested so far.

The present research on the effects of target eccentricity and stimulus category on *visual search of relations* –i.e., visual search that relies on the encoding of relations between items– was developed in five experiments. In Experiment 1, we studied the effects of target location (central *vs.* peripheral) in the search asymmetry between interacting (face-to-face) and non-interacting (back-to-back) body dyads. The target could appear at one of eight locations, four around central fixation and four at more peripheral locations. We used eye-tracking to make sure that participants maintained central fixation at the beginning of the trial, and thus verify that our manipulation of target eccentricity (central *vs.* periphery) was effective. To preview, results showed that interacting dyads were detected better than non-interacting dyads, when presented at central locations. The asymmetry was abolished, in effect reversed in the direction of an advantage for non-interacting dyads, when targets appeared at peripheral locations. Experiments 2-3 provided a replication of these results, with online testing and small variations of the original task. In Experiments 4-5, participants were tested on another variation of the task, involving interacting and non-interacting body dyads and interacting and non-interacting object pairs. Results replicated the advantage for interacting body dyads but did not show a similar advantage for object sets, demonstrating that the effects found for seemingly interacting people do not generalize to any pair of items in a meaningful relationship.

Experiment 1

In a crowded array, interacting (*i.e.*, face-to-face) dyads can be detected better than non-interacting dyads, but the opposite is also possible (Papeo et al., 2019; Vestner et al., 2019). Here we addressed how target eccentricity modulates the visual search for body dyads, 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 cells of equal size (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.

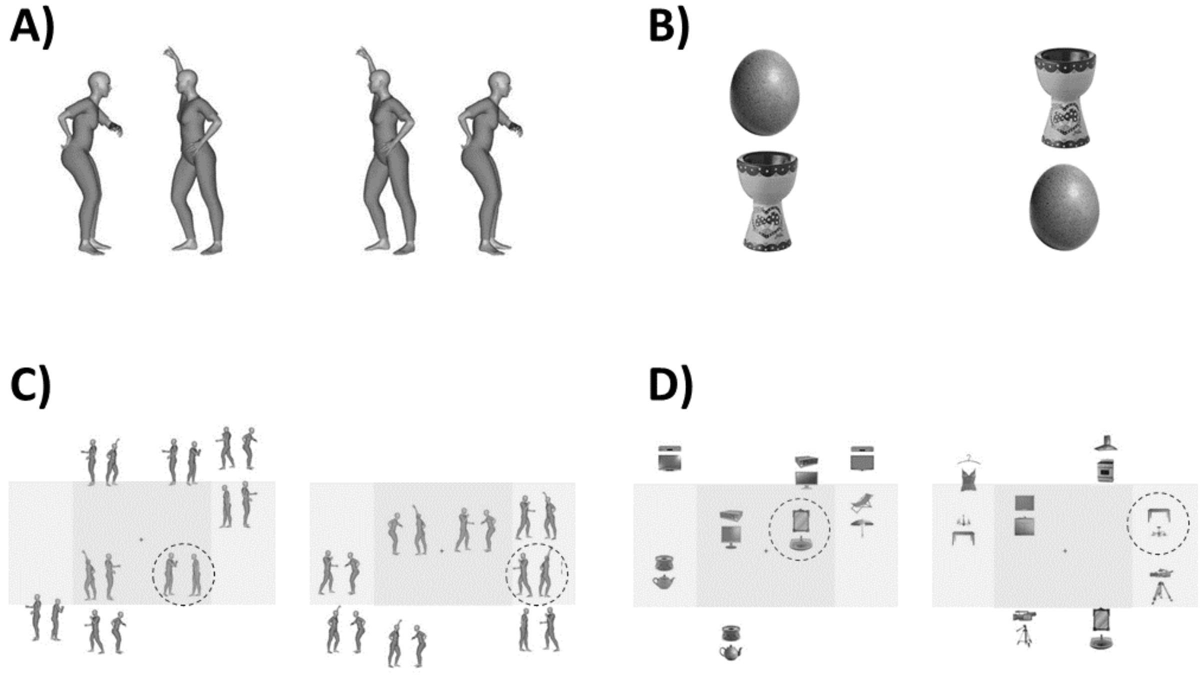

Figure 1. Stimuli of Experiments 1-4. A) Examples of interacting and non-interacting body dyads used in Experiments 1-5. **B)** Examples of functionally interacting and non-interacting object pairs used in Experiments 4-5. **C)** Examples of body-dyad arrays used in Experiments 1-5. Left: condition with 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 Experiments 4-5. 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 within the grey rectangles: 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 during the experiments. Note that all experiments involved arrays with set size 8 (4 dyads/pairs in each half of the array) as shown in the figure. In addition, Experiment 2 included conditions with set size 4 (2 dyads in each half of the array), and Experiments 4 included conditions with set size 10 (5 dyads/pairs in each half of the array). Also note that in Experiments 1-3, arrays of body dyads were symmetrical (each half of the screen was a mirror of the other except for the target). Here examples from Experiments 4-5 are shown, where arrays of bodies were not symmetrical, in order to match the presentation of arrays of objects.

Procedure

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 did not begin until the participant fixated 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). 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), but participants were not informed of this feature of the task. After the search array disappeared, a blank screen was shown until the participant responded, then, 1400 ms after, the next trial began. 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; *ez*; 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 was 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 and non-interacting targets. The same analytic approach was used in all experiments, as well as RTs that we report in Supplementary Material 1. 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. Eye-tracking samples for computing dwell times were raw coordinates of gaze location recorded by the eye-tracker, fixations were series of consecutive samples clustered by spatial proximity (defined by a velocity threshold).

Results

One participant’s mean accuracy was 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 included in the analysis. Accuracy was analyzed in a 2 (target configuration: interacting, non-interacting) × 2 (target eccentricity: central, peripheral) repeated-measures ANOVA (see Supplementary material 1 for RTs).

Accuracy. As shown in Figure 2, participants were more accurate at detecting the interacting dyads than the non-interacting dyads when targets were in central locations, but not in peripheral locations. In the latter condition, the effect even tended to reverse toward an advantage for non-interacting dyads.

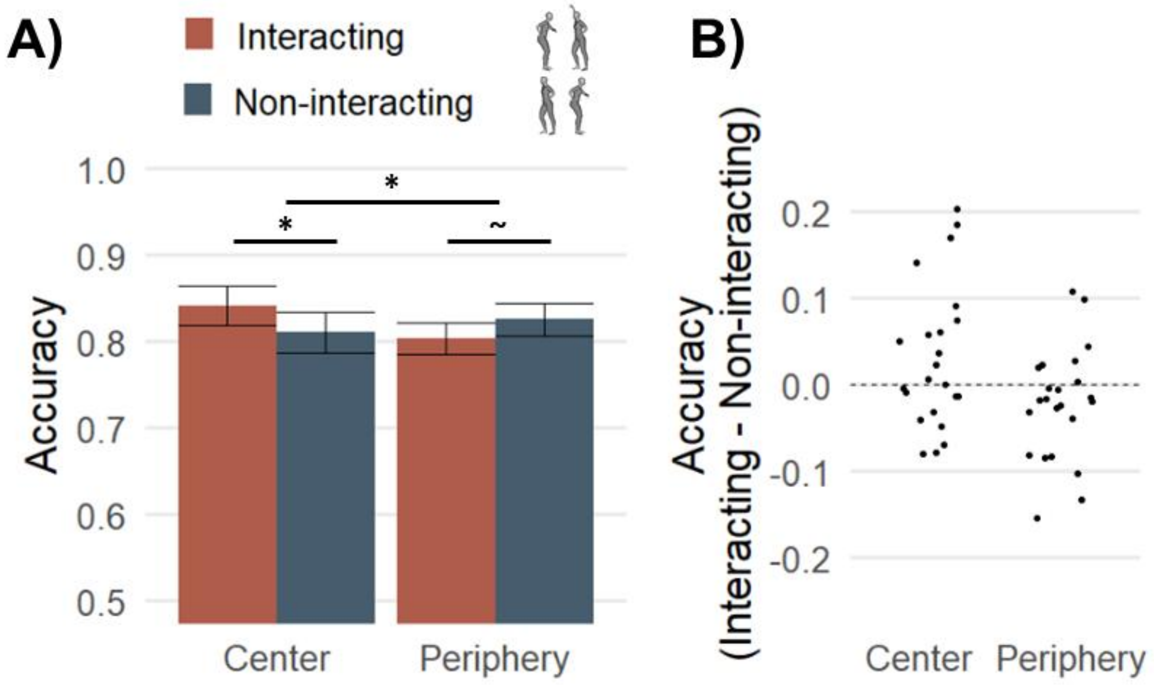

Figure 2. Results of Experiment 1. (A) Mean Accuracy as a function of target configuration (interacting/non-interacting) and target eccentricity (center/periphery). Bar plots represent the mean group accuracy with interacting dyads and non-interacting dyads; error bars are standard errors of the mean. * 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.

Statistical analysis confirmed this pattern showing a significant interaction between target configuration and eccentricity, *F*(1, 22) = 5.87, *p* = .024, $\eta_p^2 = 0.21$, with no main effect of configuration or eccentricity (see Table 1). Pairwise comparisons showed a search asymmetry between interacting and non-interacting targets at central locations, *t*(22) = 1.81, *p* = .042, *d* = 0.38 (one-tailed), 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 showed the opposite trend with targets at peripheral locations, *t*(22) = -1.66, *p* = .056, *d* = -0.35 (one-tailed), 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, $t(22) = -1.15$, $p = .262$, $d = -0.24$.

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, $F(1, 22) = 388.56$, $p < .001$, $\eta_p^2 = 0.96$, 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**,** $F(1, 22) = 1.95$, $p = .176$, $\eta_p^2 = 0.42$, and the interaction, $F(1, 22) = 0.06$, $p = .814$, $\eta_p^2 = 0.00$, 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 2), meaning that the above effects on accuracy and RTs were largely independent from overt eye movements.

Discussion

The analysis of accuracy rates showed that 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. 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. The effect was abolished with targets at peripheral locations: here, non-interacting targets tended to be reported more accurately than interacting targets.

Consistent with previous reports (Papeo et al., 2019), accuracy proved more sensitive than RTs to the effects of relations on visual search, most likely because of the short stimulus presentation time (see also Kaiser et al., 2014). RTs either did not show effects or show effects in line with the accuracy results, ruling out effects of speed-accuracy trade-off (see Supplementary material 1 and Supplementary Table 1 for a full report of the RT analyses). Finally, eye-tracking data were primarily collected to make sure that participants fixated the center of the screen at the beginning of a trial. While confirming this circumstance, these data also showed that the participants’ eyes remained in the central area for most of the trial duration, although they were extremely accurate (>80%) in detecting targets at the periphery. This suggests that the behavioral (accuracy and RTs) effects were largely independent from saccade preparation and overt eye-movements, and rather reflected preattentive processing of the stimuli and/or effects of covert attention (Hanning & Deubel, 2020; Hunt et al., 2019; Li et al., 2021; Souto & Kerzel, 2021). More naturalistic and less time-constrained exploration of visual scenes could highlight effects in the overt looking behavior, detectable with eye-tracking. In line with this, in a recent study, using eye-tracking with stimuli presented for 2.5 to 5 sec, it was shown than human adults, children (and even macaque monkeys) looked preferentially at the part of the visual field showing facing (*vs.* non-facing) bodies (Goupil et al., 2024). Similarly, another study reported that during free viewing of naturalistic scenes, presented for 5 sec, participants dwelled longer on human dyads (vs. other areas of the scene), and even more so when the two individuals interacted (Skripkauskaite et al., 2023). These effects captured in the overt looking behavior may reflect slower processes than those observed here.

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. Differences in performance depending on set size can be useful to determine to what extent the task involves serial search throughout the array: in serial search, performance becomes less efficient for the larger set size (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 procedure

We created 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 60 cm (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 was analyzed in a 2 (target configuration: interacting, non-interacting) × 2 (target eccentricity: central, peripheral) × 2 (set size: set 4, set 8) repeated-measures ANOVA (see Supplementary material 1 for RTs).

Accuracy. As shown in Figure 3, participants were more accurate at detecting the interacting target than the non-interacting target when the target was in central locations, but not in peripheral locations. In the latter condition, the effect tended to reverse toward an advantage for non-interacting dyads. Relative to conditions with set size of 8, performance in conditions with set size of 4 was overall higher, and less sensitive to differences across conditions, suggesting a ceiling effect. In summary, results of Experiment 2 in the conditions with set size of 8 fully replicated the results of Experiment 1.

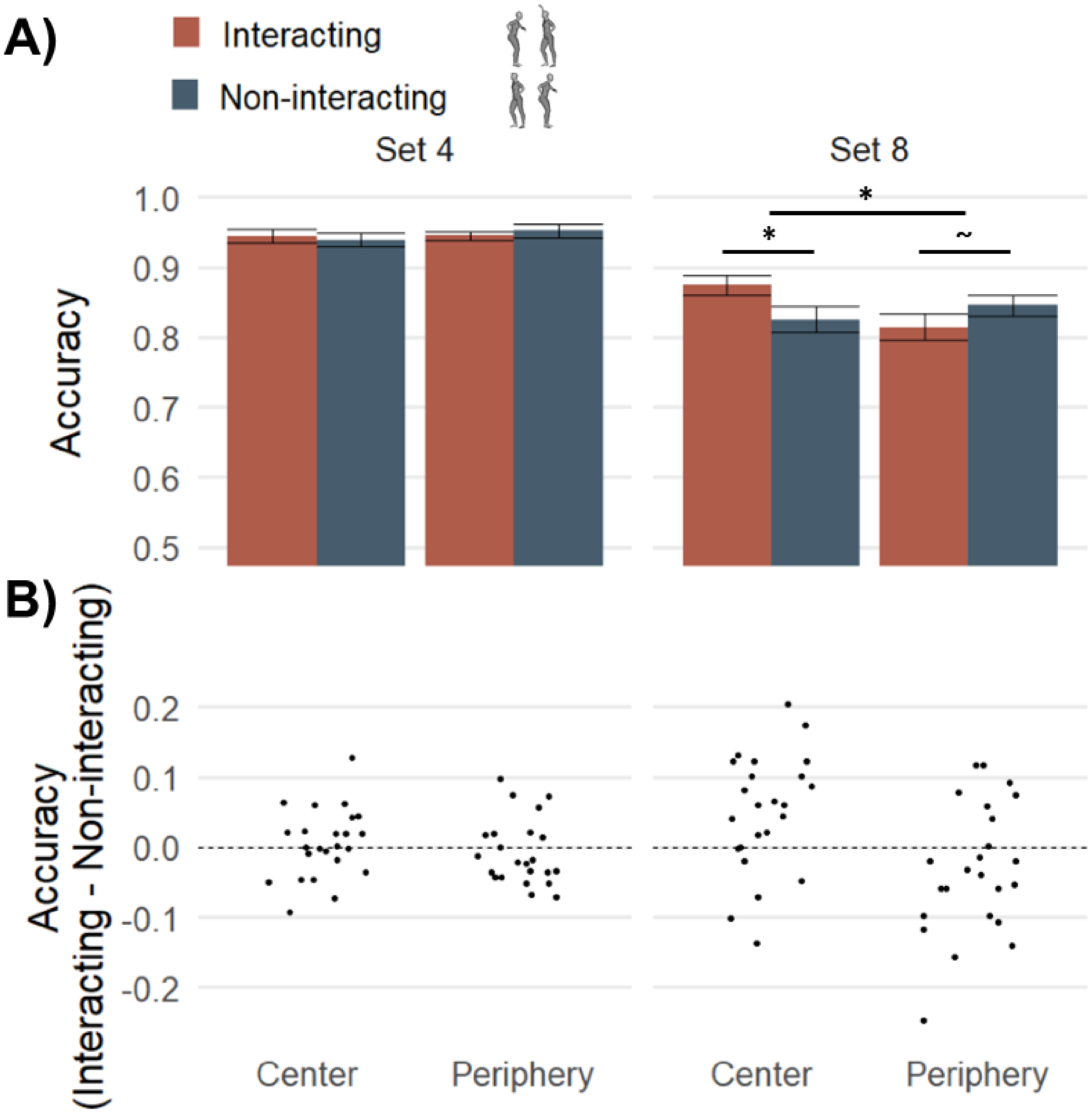

Figure 3. Results of Experiment 2. (A) Mean Accuracy as a function of target configuration (interacting/non-interacting), target eccentricity (center/periphery) and set size (four/eight dyads). Bar plots represent the mean group accuracy with interacting and non-interacting dyads; error bars are standard 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.

The statistics confirmed this observation. Indeed, we found an effect of set size, *F*(1, 23) = 88.58, *p* < .001, η_p^2 = 0.95, showing overall better performance in conditions with set size 4 *vs.* 8. We also found an interaction between target configuration and eccentricity, $F(1, 23) = 8.04$, $p = .009$, $\eta_p^2 = 0.48$, and an 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 (see Table 2).

Effect of eccentricity in the search for interacting vs. non-interacting targets. To understand the three-way interaction (target configuration x target eccentricity x set size), 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 with set-size-8 conditions. In particular, with set size of eight, the critical target configuration by eccentricity interaction was significant, $F(1, 23) = 13.11$, $p = .001$, $\eta_p^2 = 0.36$ (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 ($M_{interacting} = 0.87$, $SD = 0.07$; $M_{non\text{-}interacting} = 0.83$, $SD = 0.09$; $t(23) = 2.85$, $p = .004$, $d = 0.58$; one-tailed), but not with targets at peripheral locations. In the latter condition, again, the opposite trend was observed: better performance with non-interacting, than with interacting targets ($M_{interacting} = 0.81$, $SD = 0.09$, $M_{non\text{-}interacting} = 0.85$, $SD = 0.07$; $t(23) = -1.63$, $p = .059$, $d = -0.33$; one-tailed). Moreover, interacting targets were detected better in 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, $t(23) = -1.11$, $p = .278$, $d = -0.23$. No effects were found in conditions with set size of four (configuration: $F(1, 23) = 0.02$, $p = .894$, $\eta_p^2 = 0.00$; eccentricity: $F(1, 23) = 0.67$, $p = .421$, $\eta_p^2 = 0.03$; configuration by eccentricity: $F(1, 23) = 0.63$, $p = .435$, $\eta_p^2 = 0.03$).

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 ($F(1, 23) = 14.01$, $p = .001$, $\eta_p^2 = 0.38$; effect of eccentricity: $F(1, 23) = 7.73$, $p = .011$, $\eta_p^2 = 0.37$; effect of set size: $F(1, 23) = 43.07$, $p < .001$, $\eta_p^2 = 0.87$), 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, $F(1, 23) = 93.24$, $p < .001$, $\eta_p^2 = 0.85$, 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, $F(1, 23) = 1.78$, $p = .195$, $\eta_p^2 = 0.11$, or interaction, $F(1, 23) = 0.16$, $p = .694$, $\eta_p^2 = 0.01$.

Discussion

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. The same accuracy pattern was not found with set size of four, where performance approached ceiling, possibly reducing the sensitivity to differences across conditions. Moreover, the search for interacting targets was less affected by the number of distractors (set size) when the target was at the center than in the periphery. This pattern is in line with the hypothesis that interacting dyads may be both *a)* easier to process-and-reject as distractors, an effect that is more visible when the search for a target requires processing many distractors (i.e., the target is in the periphery), and that is susceptible to the number of distractors; and *b)* easier to process-and-accept as targets, an effect more visible when there are fewer distractors to process (i.e., the target is in the center). Finally, 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 (see Supplementary material 1).

Experiment 3

Experiments 1-2 showed that the search advantage for interacting dyads emerged with targets presented at the attended (central) location. Put in another way, when the target was in the focus of attention (and therefore the search through the array was minimal), performance emphasized the differences in the capacity of the targets to be processed-and-accepted, yielding an advantage for interacting over non-interacting targets. In addition, Experiments 1-2 showed that the pattern reversed toward an advantage for non-interacting dyads, with targets at the periphery. One possibility is that when the target appears in peripheral locations, performance relies more heavily on how efficiently the participant can go through the array, process and reject the distractors (Kaiser et al., 2014; Papeo et al., 2019). If interacting dyads are processed more efficiently than non-interacting dyads, the search through an array with a majority of interacting dyads should be more efficient than the search through an array with a majority of non-interacting dyads. As a result, with targets at the periphery, non-interacting dyads among interacting dyads are found more efficiently than *vice versa*. If this reasoning is correct, the advantage for non-interacting over interacting targets at the periphery could be emphasized by extending the stimulus duration, thus allowing more time for serial search in the periphery. We tested this prediction in Experiment 3, where everything was identical to Experiment 1, except for two features: 1) the experiment was carried out online, and 2) stimulus duration (the time of presentation of search arrays) was increased by 50%, for a total of 1200 ms.

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.

Stimuli and procedure

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, we only included arrays with set size of 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 of the remaining participants were analyzed in a 2 (target configuration: interacting, non-interacting) × 2 (target eccentricity: central, peripheral) repeated-measures ANOVA (see Supplementary material 1 for RTs).

Accuracy. As shown in Figure 4, participants' performance in Experiment 3 replicated the pattern of Experiments 1-2, showing an advantage for interacting targets in central locations and for non-interacting targets in peripheral locations.

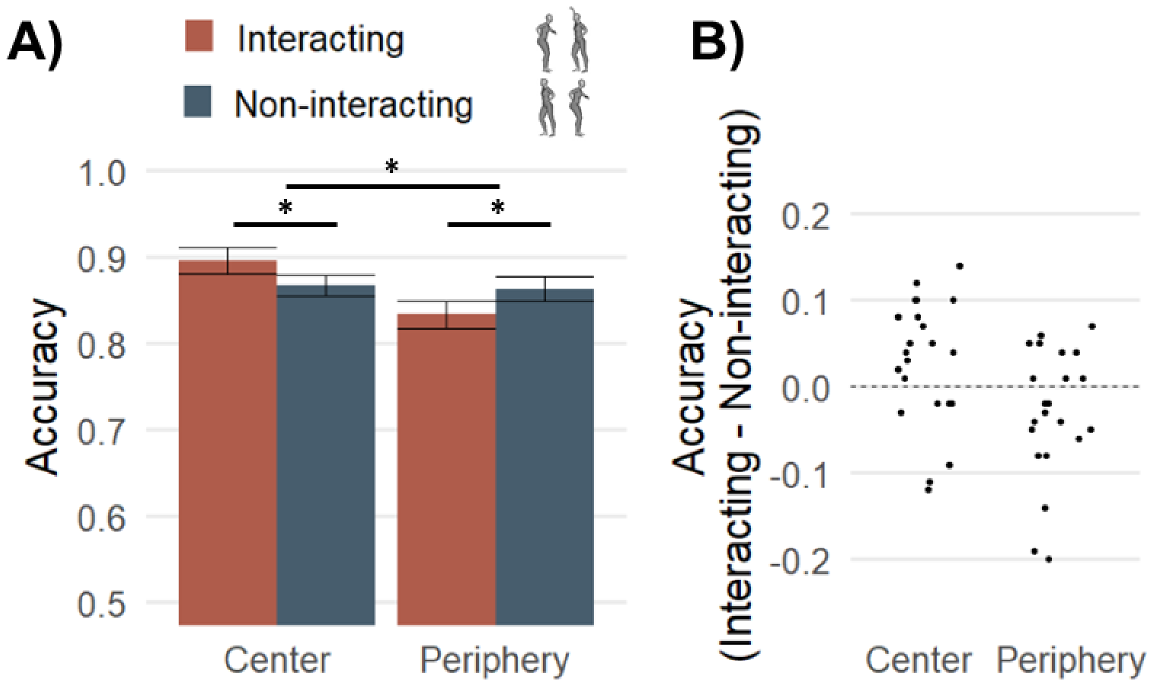

Figure 4. Results of Experiment 3. (A) Mean Accuracy as a function of target configuration (interacting/non-interacting) and target eccentricity (center/periphery). Bar plots represent the mean group accuracy with interacting and non-interacting dyads; error bars are standard errors from the mean. * denotes 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.

Confirming this observation, statistical analyses showed an interaction between target configuration and eccentricity, $F(1, 21) = 7.44$, $p = .013$, $\eta_p^2 = 0.26$ (see also Table 3). 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; one-tailed), and the inverse asymmetry at peripheral locations, *t*(21) = -1.87, *p* = .038, *d* = -0.40 (one-tailed), 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 non-interacting targets, *t*(21) = 0.26, *p* = .797, *d* = 0.06.

Between-subject analysis of Experiments 1-3.

To test whether any of the variations across the three experiments (in-lab *vs.* online testing and/or different the stimulus presentation time) significantly changed the pattern of performance, we analyzed the data of the three experiments together, in a 3 (Experiment: 1, 2, 3) × 2 (target configuration: interacting, non-interacting) × 2 (target eccentricity: central, peripheral) repeated-measures ANOVA with "Experiment" as a between-subjects factor. Note that, for Experiment 2, the only one with two levels of set size, we considered only values in the conditions with set size 8. Results confirmed the advantage for interacting dyads with target in central locations and the advantage for non-interacting dyads with targets at peripheral locations (target configuration x target eccentricity interaction *F*(1, 66) = 25.56, *p* < .001, ηp^2 = 0.28), with no differences across experiments (there was no main effect of Experiment or interaction of this, with other factors (Experiment: F(2,66) = 2.36, p = .102, ηp^2 = 0.33; Experiment x configuration: F(2,66) = 0.17, p = .847, ηp^2 = 0.01; Experiment x eccentricity: F(2,66) = 0.69, p = .503, ηp^2 = 0.03; Experiment x eccentricity x configuration: F(2,66) = 0.43, p = .654, ηp^2 = 0.01).

Discussion

The longer stimulus presentation time 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. Furthermore, the longer stimulus presentation emphasized the advantage for non-interacting targets at the periphery. This result encourages the thinking that target presentation at peripheral locations induced serial search through the array and that this process benefited from a meaningful, structured configuration of the distractors. Altogether Experiments 1-3 demonstrate a processing advantage for interacting dyads manifested itself in a) an advantage in searching for interacting targets when performance depends on how efficiently a target is recognized (i.e., processed and accepted as such), and b) an advantage in searching across interacting distractors when performance depends on how efficiently distractors can be processed and rejected.

Experiment 4

Experiments 1-3 showed that 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 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). We manipulated the set size of the search arrays to assess to what extent performance was affected by this factor. We chose set sizes of 8 and 10, rather than 4 and 8 as in Experiment 4, because the results of Experiment 4 suggested that visual search with set size of 4 was too easy and therefore less sensitive to differences between conditions.

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 procedure

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 (i.e., only one repetition of the same dyad in each array and different dyads in the two halves of the array) to match the object-pair arrays.

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 stimulus-type condition, with either interacting or non-interacting targets. Before each block, participants were familiarized with the task using 8 familiarization-trials. 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 were analyzed in a 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 ANOVA (see Supplementary material 1 for RTs).

Accuracy. As shown in Figure 5, the pattern for body dyads and object pairs was qualitatively different. For body dyads, there was an advantage for interacting targets when targets were presented in central locations, while performance was better with non-interacting targets when targets were presented in peripheral locations. For object sets, regardless of set size and target eccentricity, non-interacting targets were found more easily than interacting targets.

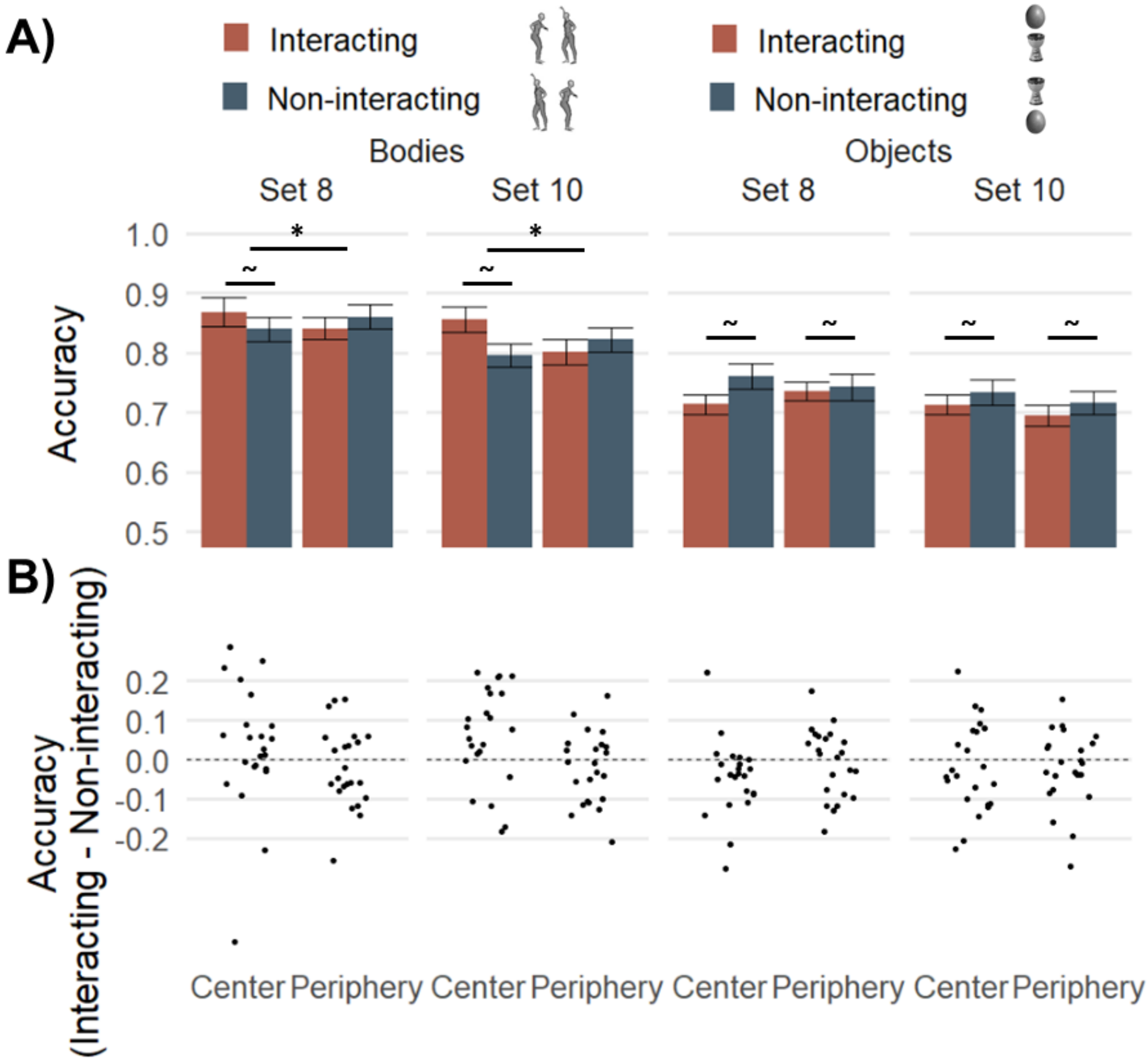

Figure 5. Results of Experiment 4. (A) Mean Accuracy as a function of target type, target configuration (interacting/non-interacting), target eccentricity (center/periphery) and set size. Bar plots represent the mean group accuracy with interacting dyads (light brown) and non-interacting dyads (dark 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.

This observation was supported by statistical analyses. Overall participants were more accurate with bodies than with objects (effect of target type: *F*(1, 22) = 114.132, $p < .001$, $\eta_p^2 = 0.93$; $M_{bodies} = 0.84$, $SD = 0.07$; $M_{objects} = 0.73$, $SD = 0.07$), and with the smaller than the larger set size ($F(1, 22) = 27.12$, $p < .001$, $\eta_p^2 = 0.48$; $M_{eight} = 0.80$, $SD = 0.06$; $M_{ten} = 0.77$, $SD = 0.07$). Importantly, there was 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 (see Table 4).

To understand this interaction, we computed two 2 (target configuration: interacting, non-interacting) × 2 (target eccentricity: central, peripheral) repeated-measures ANOVAs for body- and object-trials, separately, collapsing conditions with set size 8 and 10. 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, there was a search asymmetry in favor of interacting dyads, with targets in central locations ($M_{interacting} = 0.86$, $SD = 0.10$; $M_{non\text{-}interacting} = 0.82$, $SD = 0.08$; $t(22) = 1.68$, $p = .054$, $d = 0.35$; one-tailed). Numerically, the search for the target at the periphery was better for non-interacting than for interacting dyads, although this difference was not significant $M_{interacting} = 0.82$, $SD = 0.08$; $M_{non\text{-}interacting} = 0.84$, $SD = 0.09$; $t(22) = -1.27$, $p = .108$, $d = -0.27$; one-tailed).

For object pairs, the ANOVA only showed a trend for the effect of configuration, $F(1, 22) = 3.49$, $p = .075$ $\eta_p^2 = 0.18$: regardless of target location, non-interacting targets tended to be detected more successfully than interacting targets (Table 4).

Discussion

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 results of our previous experiments, we found a search advantage (in accuracy rates) for interacting dyads in central locations. With targets at peripheral locations, performance was numerically better in the search for non-interacting (*vs.* interacting) targets. The same effect was found with object pairs regardless of target eccentricity: whether at central or peripheral locations, participants were more likely to report non-interacting object pairs than interacting pairs. Thus, the effect of social relationship as implied by body positioning (facing/non-facing) does not extend to non-social relations. Non-interacting objects are easier to detect than interacting objects. This may be because interacting objects break real-world regularities yielding a sort of “oddity effect”, or because object sets in meaningful (*e.g.*, functionally relevant) spatial relations are easier to reject as distractors. Either way, interacting objects affects visual search in a different way than interacting people. An online version of Experiment 4 partly replicated these findings (see Supplementary Experiment 1). However, both the in-lab and the online experiment suffered from a dramatic difference in accuracy rates with bodies *vs.* objects (see main effects of target type), which could undermine conclusions driven by the comparison between stimulus types. To overcome this limitation, in Experiment 5 we modified the task parameters to match the accuracy levels between conditions with body dyads and object pairs.

Experiment 5

Experiment 4 showed different patterns of performance with body dyads and object pairs. However, searching through object arrays was much more difficult than searching through body arrays. In Experiment 5, we sought to confirm the results of Experiment 4 with comparable performance across body and object conditions. To this end, we increased the task difficulty for body trials by decreasing the stimulus duration (and therefore the search time) to 600ms, and decreased the task difficulty for object trials by increasing the stimulus duration to 1600ms. Like Experiments 2-3, Experiment 5 was carried out online with the stimulus-type (bodies or objects) manipulated between-subjects and only one set size (8), to minimize the duration of the task.

Methods

Participants

A sample size of 70 (35 per target type) was selected based on a power analysis (*Superpower*; Lakens & Caldwell, 2021) that estimated the minimal sample size for an interaction between target type (bodies/objects), target eccentricity (center/periphery) and target configuration (interacting/non-interacting). The third-order configuration x eccentricity x category interaction was modelled from the means of Experiments 1-3 showing a configuration x eccentricity interaction, compared to the grand average of Experiments 1-3 simulating no interaction (α = .05, β = 0.90). Eighty new healthy participants (27 females, 2 other; age *M* = 31, *SD* = 7.98) were recruited and tested on Testable.org, after giving the informed consent. Ten participants were removed from all analyses (nine performed at chance level and one had response times 2.5 SDs slower than the group mean), yielding a final sample of 70 participants.

Stimuli and procedure

To match accuracy rates between target types, stimulus presentation was increased to 1600ms for objects and reduced to 600ms for bodies. To reduce the experiment duration and thus improve the quality of the data (see discussion of Supplementary Experiment 1), we only included one set-size condition (eight) and manipulated the stimulus between-subjects. To make the eccentricity condition as effective as possible, the instructions emphasized that participants had to look at the central fixation cross at the beginning of each trial. Two sets of 400 search arrays (one with body dyads and one with object pairs) were created. Everything else was identical to Experiment 4.

Results

One participant with mean RTs 2.5 *SD* slower than the group mean was excluded and replaced. All other participants had mean accuracy within 2.5 *SD* from the group mean and were included in analysis. Mean accuracy rates were analyzed in an ANOVA with target configuration (interacting/non-interacting) and target eccentricity (central/peripheral) as within-subjects factors, and target type (bodies/objects) as the only between-subjects factor (see Supplementary material 1 for RTs).

Accuracy. As shown in Figure 6, accuracy rates were comparable between body- and object-conditions. However, in the visual search through bodies, participants detected interacting targets better than non-interacting dyads; the opposite was true for the visual search through objects.

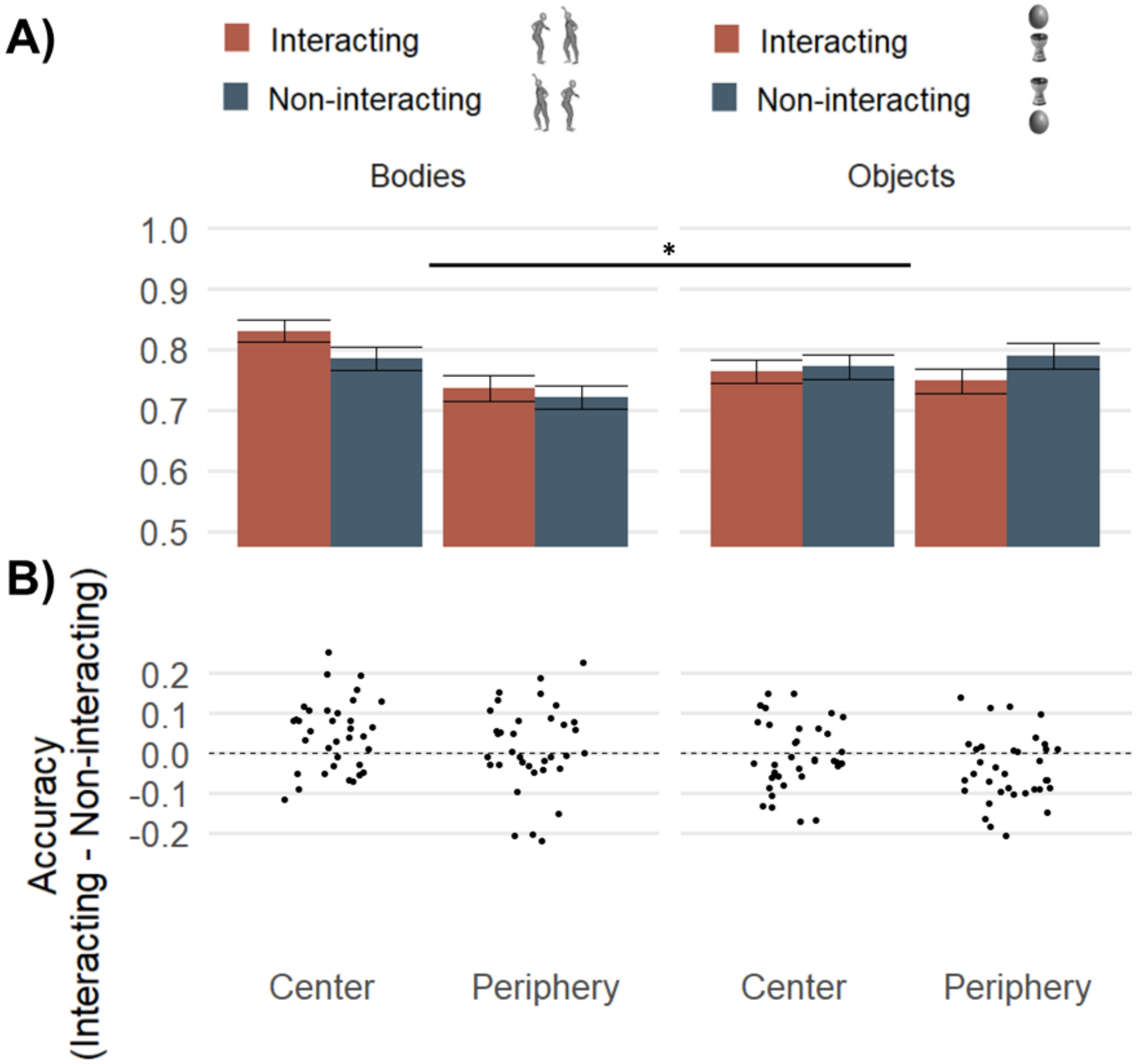

Figure 6. Results of Experiment 5. (A) Mean Accuracy as a function of target type (bodies/objects) target eccentricity (center/periphery) and target configuration (interacting/non-interacting). Bar plots represent the mean group accuracy with interacting dyads (light brown) and non-interacting dyads (dark blue); error bars are standard errors from the mean. * denote the significant interaction (p < .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.

Statistics supported this pattern (Table 5). Importantly, there was no main effect of target type $F(1,68) = 0.00$, $p = .998$, $\eta_p^2 = 0.00$, meaning that accuracy was comparable between conditions with bodies and objects. Moreover, we found an interaction between configuration and target type $F(1,68) = 9.36$, $p = .003$, $\eta_p^2 = 0.21$, reflecting the fact that participants were more accurate in finding interacting (*vs.* non-interacting) bodies ($M_{interacting} = 0.78$, $SD = 0.10$; $M_{non\text{-}interacting} = 0.75$, $SD = 0.10$; $t(34) = 2.49$, $p = .009$, $d = 0.42$; one-tailed), and more accurate in finding non-interacting (*vs.* interacting) objects ($M_{interacting} = 0.76$, $SD = 0.11$; $M_{non\text{-}interacting} = 0.78$, $SD = 0.12$; $t(34) = -1.87$, $p = .035$, $d = -0.32$; one-tailed).

Two other interactions showed that: a) accuracy with bodies was overall better at the center than at the periphery, whereas accuracy with objects was comparable across central and peripheral locations (eccentricity x type: $F(1, 68)=26.18$, $p< .001$, $\eta p^2=0.36$; bodies: $M_{center} = 0.81$, $SD = 0.10$; $M_{\text{periphery}} = 0.73$, $SD = 0.11$, $t(34) = 5.87$, $p < .001$, $d = 0.99$; objects: $M_{center} = 0.77$, $SD = 0.11$; $M_{\text{periphery}} = 0.77$, $SD = 0.11$, $t(34) = -0.11$, $p = .914$, $d = -0.02$), and b) accuracy at the center was higher for interacting (*vs.* non-interacting) pairs, with no difference at the periphery (configuration x eccentricity: $F(1, 68)=6.30$, $p=.014$, $\eta p^2=0.09$; center: $M_{interacting} = 0.80$, $SD = 0.11$; $M_{non\text{-}interacting} = 0.78$, $SD = 0.12$; $t(69) = 1.75$, $p = .084$, $d = 0.21$; periphery: $M_{interacting} = 0.74$, $SD = 0.12$; $M_{non\text{-}interacting} = 0.76$, $SD = 0.12$; $t(69) = -1.13$, $p = .261$, $d = -0.14$).

Discussion

Like Experiment 4, Experiment 5 revealed different patterns of performance in visual search across body dyads and across object pairs. Experiment 5 showed the same advantage for interacting body dyads in central locations, as seen in Experiments 1-4. However, unlike Experiments 1-4, Experiment 5 showed an advantage also for interacting targets at the periphery, failing to replicate the advantage for non-interacting dyads at the periphery. Our interpretation is that the advantage for non-interacting dyads at the periphery did not emerge because the short stimulus presentation time (600ms) reduced or hindered serial search thorough the distractors. As a result, performance emphasized only one aspect of the advantage for interacting dyads: the more efficient processing of interacting dyads when they are targets. In this perspective, this result can be seen as the counterproof of increasing the search time for body arrays in Experiment 3 (1200ms), which yielded a larger advantage (in terms of effect size) for non-interacting targets at the periphery compared to tasks with shorter stimulus presentation time (800ms in Experiments 1-2).

Reducing the presentation time for body trials (and increasing the time for object trials) allowed matching accuracy levels between stimulus-types, facilitating the comparison between the two. Experiment 5 thereby confirmed a difference in the deployment of attention during visual search with body dyads vs. object pairs, implying different mechanisms for processing social and non-social relations.

General discussion

The current study addressed how spatial arrangements of items implying meaningful relations (e.g., social interaction implied by *facingness* between two people) affected 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 interacting dyads in the visual field affected search; and *c)* whether the pattern of search performance with body dyads generalized to object pairs instantiating another type of high-level relation (*i.e.*, objects in spatial configurations functional to common usage).

Results reveal a complex pattern of search asymmetries. For body dyads, interacting targets among non-interacting distractors were detected better than non-interacting targets among interacting distractors. This advantage for interacting dyads was consistently found when interacting target appeared in central location, that is, in a location that was in the participant's focus of attention (Experiments 1-5). When the target appeared at peripheral locations, the advantage for interacting dyads reversed in favor of non-interacting dyads (Experiments 1, 2, 4), an effect that was enhanced with a longer search time (Experiment 3) and abolished with a shorter search time (Experiment 5). The pattern for objects was markedly different (Experiments 4-5): there was no advantage of interacting over non-interacting targets, but the opposite effect, independent of target eccentricity.

The advantage for interacting body dyads 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 show that interacting targets are found more efficiently when they appear at the attended (central) location. But, if the task requires it (target at peripheral locations) and time allows it (long enough stimulus presentation times), interacting dyads can also be searched through more efficiently than non-interacting dyads, yielding an advantage for non-interacting targets among interacting distractors. Thus, there are two ways in which interacting dyads affect visual search: they are more efficient to *process-and-accept* as targets and more efficient to *process-and-reject* as distractors. Whether one or the other mechanism dominates performance depends on how many distractors need to be processed: with only few distractors to process (target in central location), visual search would reflect how easy it is to *process-and-accept* the target (easier for interacting than non-interacting target); with more distractors to process (target in peripheral locations), visual search would reflect how easy it is to *process-and-reject* the distractors (easier for interacting than non-interacting target).

The processing advantage for interacting dyads is consistent with a number of phenomena showing attentional or perceptual advantages for this kind of stimuli. In particular, it has been shown that face-to-face bodies break faster into visual awareness relative to the same bodies presented back-to-back (Papeo et al., 2017); and 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. Moreover, functional MRI research using classification analyses showed 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).

Like interacting bodies, interacting objects tended to be processed and rejected more efficiently as distractors, compared to non-interacting objects (see also Kaiser et al., 2014). Thus, visual search generally benefited from arrays in which most elements (i.e., the distractors) are arranged to form meaningful, related sets, resulting in a search advantage for non-interacting targets. At the same time, unlike interacting bodies, interacting objects were not processed and accepted more efficiently as targets, compared to non-interacting objects. This difference between body dyads and object pairs may 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 (see Goupil et al., 2024; New et al., 2007, for perspectives on developmental and evolutionary constraints on visual attention). In contrast, spotting a group of regularly positioned objects is not typically associated with such behavioral rewards.

Differences between body dyads and object sets could also reflect visual and semantic dissimilarities in the stimuli, rather than in the attention to those stimuli. First, here, bodies were all visually similar (in fact, the very same body was shown in different postures across all dyads); whereas objects belonged to various, visually different, categories. Second, while encoding relations between bodies might merely rely on facing *vs*. non-facing discrimination, appraisal of relationships between objects might require attention to finer details. Third, body dyads and object pairs could entail different levels of representation. That is, all facing dyads could trigger a general representation of “interaction”, while each interacting object pair specified a relation that was different from the others (lamp above table, monitor above keyboard and so on). Although current perspectives propose that functional relations between objects are retrieved automatically and effortlessly (Kaiser et al., 2014; Kaiser et al., 2019), it seems reasonable to think that there was a greater demand for visual and semantic processing for object sets, compared to body dyads. This would explain the greater task difficulty in the object task compared to the body task (Experiment 4) –

matching stimulus-conditions for difficulty required more than twice the stimulus presentation time for objects than for bodies (Experiment 5).

Finally, while relations between bodies unfolded along the horizontal axis, object sets were organized vertically. Visual search for facing *vs.* non-facing objects aligned along the vertical axis (two fans, two cameras, two cameras, etc.) has been assessed in previous work. In Vestner et al. (2020; 2022), an advantage similar to the one observed for interacting bodies as targets, was found for some pairs –but not all– of facing objects whose orientation provided a directional cue (i.e., leftward or rightward). It remains unclear why the effect of interacting generalizes to some “pointing” objects (e.g., fans, cars and bikes) but not others (e.g., guns, chairs and shoes). Moreover, a direct comparison with our results is limited by important differences in the paradigms. Vestner et al*.* presented arrays of four stimuli around central fixation (alike our “central” condition) for unlimited time and, strictly speaking, 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 they were used as targets among other (neutral) distractors. Leaving aside these differences, Vestner et al.’s work suggests that *facingness* on its own is not sufficient to induce a visual search advantage, but this effect is contingent to the stimulus category.

Adding to this growing literature, here, we addressed whether *any* pair that forms a meaningful configuration gives rise to the attentional advantages found for interacting people. Results suggest that there are shared but also different mechanisms for processing social and non-social visual relational information. Future research should investigate why some effects but not others generalize across social and non-social stimuli/relations, and should extend the present comparison of socially interacting bodies and functionally interacting objects to other classes of stimuli and relationships to clarify what type of relational information influences attention and how. Moreover, while a common serial search mechanism may yield different effects (more efficient search for interacting *vs.* non-interacting dyads) depending on the number of distractors to process, it is possible that other mechanisms (e.g., attentional capture) are involved (Papeo et al., 2019). The search mechanism (or mechanisms) underlying the present effects remains a question for future research.

In conclusion, the relationship implied by the spatial arrangement of individual items can facilitate both the *search for* a target and the *search through* the distractors. Effects of relations on visual search also depend on the stimulus category (people or objects) or domain (social or non-social). Altogether, these effects demonstrate that new units of attention and perception emerge spontaneously from spatial arrangements that imply higher-level relationships (e.g., social interaction or functional common usage), structuring the visual environment in a way that facilitates visual search.

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Table 1

ANOVAs on accuracy and response times in Experiment 1

	Accuracy				*RTs*			
	df	*F*	*p*	*ηp²*	*df*	*F*	*p*	*ηp²*
Configuration	1, 22	0.17	.687	0.01	1, 22	0.25	.625	0.06
Eccentricity	1, 22	0.97	.336	0.05	1, 22	7.52	.012	0.42
Configuration x Eccentricity	1, 22	5.87	.024	0.21	1, 22	0.67	.421	0.03

Table 2

ANOVAs on accuracy and response times in Experiment 2

	Accuracy				*RTs*			
	df	*F*	*p*	*ηp²*	*df*	*F*	*p*	*ηp²*
Configuration	1, 23	0.28	.600	0.03	1, 23	0.00	.974	0.00
Eccentricity	1, 23	0.66	.425	0.07	1, 23	0.01	.915	0.00
Set size	1, 23	88.58	< .001	0.95	1, 23	17.4	< .001	0.30
Configuration x Eccentricity	1, 23	8.04	.009	0.48	1, 23	0.98	.333	0.02
Configuration x Set size	1, 23	0.44	.513	0.04	1, 23	0.42	.524	0.01
Eccentricity x Set size	1, 23	3.15	.089	0.23	1, 23	1.15	.295	0.05
Configuration x Eccentricity x Set size	1, 23	11.62	.002	0.34	1, 23	1.27	.271	0.05

Table 3

ANOVAs on accuracy and response times in Experiment 3

	Accuracy				*RTs*			
	df	*F*	*p*	*ηp²*	*df*	*F*	*p*	*ηp²*
Configuration	1, 21	0.01	.938	0.00	1, 21	2.24	.150	0.38
Eccentricity	1, 21	5.79	.025	0.32	1, 21	17.08	< .001	0.30
Configuration x Eccentricity	1, 21	7.44	.013	0.26	1, 21	0.09	.769	0.00

Table 4

ANOVAs on accuracy and response times in Experiment 4

	Accuracy				*RTs*			
	df	*F*	*p*	*ηp²*	*df*	*F*	*p*	*ηp²*
Configuration	1, 22	0.55	.467	0.04	1, 22	0.86	.364	0.39
Eccentricity	1, 22	0.90	.353	0.07	1, 22	11.89	.002	0.62
Set size	1, 22	27.12	< .001	0.48	1, 22	43.32	< .001	0.77
Type	1, 22	114.13	< .001	0.93	1, 22	35.52	< .001	0.99
Configuration x Eccentricity	1, 22	1.65	.213	0.13	1, 22	4.63	.043	0.21
Configuration x Set size	1, 22	0.69	.414	0.03	1, 22	0.54	.469	0.04
Configuration x Type	1, 22	2.04	.167	0.27	1, 22	3.35	.081	0.58
Eccentricity x Set size	1, 22	1.81	.193	0.06	1, 22	0.02	.889	0.00
Eccentricity x Type	1, 22	0.00	1	0.00	1, 22	0.55	.467	0.06
Set size x Type	1, 22	0.75	.396	0.02	1, 22	6.26	.020	0.34
Configuration x Eccentricity x Type	1, 22	5.71	.026	0.33	1, 22	1.47	.238	0.10
Configuration x Eccentricity x Set size	1, 22	3.41	.078	0.09	1, 22	1.20	.286	0.11
Configuration x Set size x Type	1, 22	0.13	.717	0.01	1, 22	0.47	.502	0.04
Eccentricity x Set size x Type	1, 22	0.16	.695	0.01	1, 22	0.06	.809	0.00
Configuration x Eccentricity x Set size x Type	1, 22	0.02	.900	0.00	1, 22	1.08	.311	0.05

Table 5

ANOVAs on accuracy and response times in Experiment 5

	Accuracy				*RTs*			
	df	*F*	*p*	*ηp²*	*df*	*F*	*p*	*ηp²*
Configuration	1, 68	0.10	.754	0.00	1, 68	0.05	.826	0.02
Eccentricity	1, 68	25.06	< .001	0.35	1, 68	40.70	<.001	0.50
Type	1, 68	0.00	.998	0.00	1, 68	53.28	< .001	0.99
Configuration x Eccentricity	1, 68	6.30	.014	0.09	1, 68	2.14	.148	0.03
Configuration x Type	1, 68	9.36	.003	0.21	1, 68	0.24	.625	0.08
Eccentricity x Type	1, 68	26.18	< .001	0.36	1, 68	6.80	.011	0.14
Configuration x Eccentricity x Type	1, 68	0.00	.956	0.00	1, 68	0.06	.806	0.00

Supplementary material

1 - Results on response times

Experiment 1. There was a significant effect of eccentricity, $F(1, 22) = 7.52$, $p = .012$, $\eta_p^2 = 0.42$, as participants were faster with targets at central than peripheral locations ($M_{\text{center}} = 1267$, $SD = 266$; $M_{periphery} = 1337$, $SD = 249$). No other effect was significant (see Table 1). For this and the following experiments, a table with means and standard deviations of RT values *per* condition is provided as supplementary information (Supplementary Table 1).

Experiment 2. We only found an effect of set size, $F(1, 23) = 17.40$, $p < .001$, $\eta_p^2 = 0.30$, showing that performance was faster with set size of four than eight. All other effects and interactions were not significant (Table 2; Supplementary Table 1).

Experiment 3. 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 ($M = 2061$, $SD = 282$). No other effect was significant (Table 3).

Experiment 4. Results showed that, irrespective of the target type (bodies or objects), targets were found faster in central than peripheral locations (target configuration x eccentricity, $F(1, 22) = 4.63$, $p = .043$, $\eta_p^2 = 0.21$), and that this effects was more pronounced for interacting targets, $t(22) = -3.39$, $p = .003$, $d = -0.71$, than for non-interacting targets, $t(22) = -2.27$, $p = .033$, $d = -0.47$. For other effects and interactions see Table 4.

Experiment 5. RTs showed a significant interaction between target type and eccentricity $F(1,68) = 6.80$, $p = .011$, $\eta_p^2 = 0.14$, showing a larger effect of eccentricity with bodies ($M_{center} = 1837$, $SD = 238$; $M_{periphery} = 1934$, $SD = 298$; $t(34) = -5.60$, $p < .001$, $d = -0.95$) compared to objects ($M_{center} = 2441$, $SD = 387$; $M_{periphery} = 2482$, $SD = 386$; $t(34) = -3.16$, $p = .003$, $d = -0.54$). For other effects and interactions see Table 5.

2 - Results of eye-tracking data analysis

In addition to the looking time on the center of array, we analyzed 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). First fixations were selected each trial, as the first fixation recorded after participants moved their gaze, from the area they were fixating at the beginning of the trial. Thus, first fixations were not the first gaze location at trial start, but the gaze location after the first voluntary eye-movement. Eye-movements initiated after 800 ms were not analyzed. Eye-movements were analyzed with 2 (target configuration: interacting, non-interacting) × 2 (target eccentricity: central, peripheral) repeated-measures ANOVAs.

Analyzing dwell times on target found no main effects of configuration $F(1, 22) = 0.02$, $p = .889$, $\eta_p^2 = 0.00$, or eccentricity $F(1, 22) = 0.34$, $p = .565$, $\eta_p^2 = 0.02$, and no interaction between the two $F(1, 22) = 0.01$, $p = .927$, $\eta_p^2 = 0.00$. Similarly, analyzing the number of first fixations on targets found no main effects of configuration $F(1, 22) = 1.02$, $p = .324$, $\eta_p^2 = 0.03$, or eccentricity $F(1, 22) = 2.12$, $p = .159$, $\eta_p^2 = 0.10$, and no interaction between the two $F(1, 22) = 0.37$, $p = .547$, $\eta_p^2 = 0.02$. Again, analyzing the mean onset of first fixations found no main effect of configuration $F(1, 22) = 0.77$, $p = .390$, $\eta_p^2 = 0.04$, or eccentricity $F(1, 22) = 0.01$, $p = .936$, $\eta_p^2 = 0.00$, and no interaction between the two $F(1, 22) = 0.43$, $p = .518$, $\eta_p^2 = 0.02$.

Finally, we run an additional analysis to see whether, during a trial, participants spent the same amount of time looking at the left and right side. Indeed, one strategy to perform the task could have been to focus on one side of the screen and detect whether a target was present or not. To see whether participants did so, we computed for each trial the time that subjects looked on the left side (proportion of fixations on the left: number of fixations recorded on the left side, divided by the total number of fixations on both sides). Proportions by trials were averaged for each participant and tested against chance. Results showed no difference with chance (*t*(22) = -0.10, *p* = .925; one-sample t-test; chance = 0.50), meaning that in each trial, subjects looked a comparable amount of time in the left and right field.

3- Supplementary Table 1. Mean response times (M) and standard deviations (SD) and standard errors of the mean (SEM) for each condition, for Experiments 1-5

				Experiment 1			Experiment 2			Experiment 3			Experiment 4			Experiment 5		
				M	*SD*	*SEM*	*M*	*SD*	*SEM*	*M*	*SD*	*SEM*	*M*	*SD*	*SEM*	*M*	*SD*	*SEM*
Bodies	Set 8	Central	Interacting	1265	284	59	2009	266	54	1968	300	64	1149	230	48	1851	329	40
			Non-interacting	1270	285	59	2047	245	50	2034	290	62	1169	221	46	1881	338	42
		Peripheral	Interacting	1320	265	55	2076	319	65	2022	302	64	1220	236	49	1915	318	39
			Non-interacting	1354	276	58	2075	293	60	2100	332	71	1196	249	52	1925	403	50
	Set 4 / 10	Central	Interacting				1985	806	165				1213	239	50	1892	317	39
			Non-interacting				1872	295	60				1266	292	61	1953	384	47
		Peripheral	Interacting				1838	275	56				1285	248	52	1972	372	46
			Non-interacting				1906	336	69				1279	302	63	1935	355	44
Objects	Set 8	Central	Interacting										1522	240	50	2052	497	61
			Non-interacting										1451	247	52	2082	538	66
		Peripheral	Interacting										1540	243	51	2102	536	66
			Non-interacting										1492	250	52	2128	558	69
	Set 10	Central	Interacting										1537	237	50	2068	482	59
			Non-interacting										1501	237	50	2087	482	59
		Peripheral	Interacting										1591	251	52	2111	497	61
			Non-interacting										1509	238	50	2119	499	61

4 - Supplementary Experiment 1. Online replication of Experiment 4

In Experiment 5, we replicated Experiment 4, with on-line testing on a larger sample size, powered for a three-way interaction between target type (bodies/objects), target eccentricity (center/periphery) and target configuration.

Methods

Participants. A sample size of 69 was selected based on a power analysis that considered the interaction between target type (bodies/objects), target eccentricity (center/periphery) and target configuration (interacting/non-interacting) in Experiment 4 ($F = 5.71$; $\alpha = .05$; $\beta = 0.80$; BUCSS; Anderson & Kelley, 2020). Seventy-four new healthy participants (32 females; age $M = 30$, $SD = 6.50$) were recruited and tested on Testable.org. Participants were tested after obtaining informed consent. Five participants showed performance at chance level (50%) and were discarded from the analysis and replaced.

Stimuli and procedure. Stimuli, task and procedures were identical to Experiment 4, except that, due to limited storage capacity of the online platform, a single set of 800 search arrays (400 with body dyads and 400 with object pairs) was created and used for all participants.

Results

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. As shown in Figure 6, the pattern for body dyads and object pairs was qualitatively different. In visual search through bodies, interacting targets were found more easily than non-interacting dyads, particularly in central locations. In visual search through objects, performance was overall worse relative to visual search through bodies, with no clear differences across conditions.

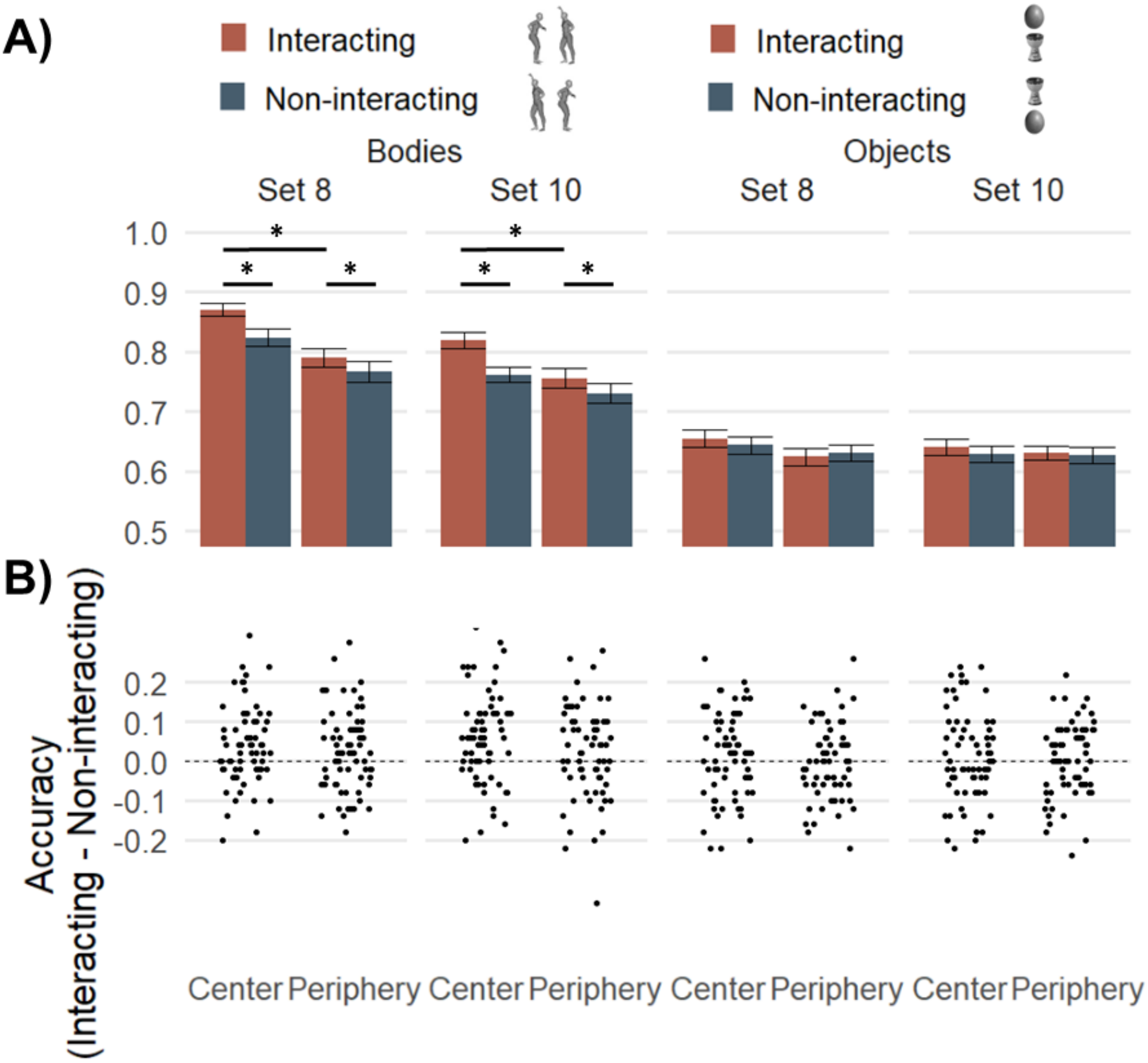

Figure 6. Results of Experiment 5. (A) Mean Accuracy as a function of target type, target configuration (interacting/non-interacting), target eccentricity (center/periphery) and set size. Bar plots represent the mean group accuracy with interacting dyads (light brown) and non-interacting dyads (dark blue); error bars are standard errors from the mean. * denote significant effects (p < .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.

This pattern was partly supported by statical reliable effects (see Supplementary Table 2). Overall participants were more accurate with bodies than with objects (effect of target type: $F(1,68) = 214.68$, $p < .001$, $\eta_p^2 = 0.96$), with the smaller than the larger set size *($F(1,68) =$*

52.71, $p < .001$, $\eta_p^2 = 0.43$), with interacting *vs.* non-interacting targets (effect of configuration: $F(1,68) = 14.17$, $p < .001$, $\eta_p^2 = 0.34$) and with targets in central *vs.* peripheral locations (effect of eccentricity: $F(1,68) = 14.96$, $p < .001$, $\eta_p^2 = 0.58$).

More importantly, an interaction between configuration and target type ($F(1,68) = 8.47$, $p = .005$, $\eta_p^2 = 0.24$) demonstrated that participants were more accurate in finding interacting ($M = 0.81$, $SD = 0.10$) than non-interacting bodies ($M = 0.77$, $SD = 0.11$), $t(68) = 4.48$, $p < .001$, $d = 0.54$, but showed no difference between interacting ($M = 0.64$, $SD = 0.09$) and non-interacting objects ($M = 0.63$, $SD = 0.10$), $t(68) = 0.62$, $p = .536$, $d = 0.08$.

Moreover, a significant configuration x eccentricity interaction ($F(1,68) = 4.23$, $p = .043$, $\eta_\mathrm{p}^2 = 0.10$) showed that accuracy was higher in the search for interacting targets ($M = 0.75$, $SD = 0.09$) *vs.* non-interacting targets ($M = 0.71$, $SD = 0.09$) in the center, $t(68) = 3.82$, $p < .001$, $d = 0.46$, but not at the periphery $t(68) = 1.66$, $p = .101$, $d = 0.20$. Although this pattern appeared more pronounced with bodies than with objects (see Figure 5), the configuration x eccentricity x target type interaction was not significant, $F(1,68) = 0.66$, $= .418$, $\eta_p^2 = 0.02$. This circumstance highlights two aspects that differed between Experiment 4 (where the three-way interaction was significant) and Experiment 5. First, in visual search through body dyads, the difference in performance between center and periphery was less pronounced in Experiment 5 (configuration x eccentricity interaction for body dyads: $F(1,68) = 3.33$, $p = .073$, $\eta_p^2 = 0.05$) than in Experiment 4 (configuration x eccentricity interaction for body dyads: $F(1, 22) = 5.52$, $p = .028$, $\eta_p^2 = 0.20$). Second, in visual search through object pairs, the trend for a higher accuracy for non-interacting (*vs.* interacting) targets seen in Experiment 4, was not found in Experiment 5. In Experiment 5, the interaction between configuration and eccentricity suggests that, like bodies, objects yielded an advantage for interacting targets at the center; however, a closer look at the performance with objects showed no difference across object-conditions (configuration x eccentricity interaction for object pairs: $F(1,68) = 1.14$, $p = 289$, $\eta_p^2 = 0.02$). See Supplementary Table 2 for a full report of the statistics.

RTs. Only the main effect of target type reached significance *F*(1, 68) = 7.53, *p* = .008, η_p^2 = 0.50), as responses were faster with bodies (*M* = 1966, *SD* = 413) than objects *M* = 2207, *SD* = 823). For other effects and interactions see Supplementary Table 2.

Discussion

Like Experiment 4, Experiment 5 revealed different patterns of performance in visual search across body dyads and across object pairs. In particular, results of Experiment 5 showed the same advantage for interacting body dyads seen in Experiment 4 (as well as Experiments 1-3). However, differently from Experiment 4, performance with objects did not show a trend for the opposite advantage (better search for non-interacting targets), and in effect it did not show differences between conditions. In the visual search across objects, the lack of sensitivity to possible differences between conditions could be related to an overall drop in accuracy, relative to the performance with bodies in Experiment 5, and also relative to the performance with objects in Experiment 4 (Experiment 4: M=0.78 ± 0.06 SD; bodies: 0.84 ± 0.07 SD; objects: 0.73 ± 0.07 SD; Experiment 5: M=0.71 ± 0.08 SD; bodies: 0.79 ± 0.09 SD; objects: 0.64 ± 0.09 SD). To recall, Experiment 4 was carried out in the lab, while Experiment 5 was carried out online. Being a long (~1 hour) and quite difficult task, the lack of control on the experimental setting in on-line data collection might have affected the quality of the data, especially in the more difficult of the two conditions, the one with objects.

5 - Supplementary Table 2. ANOVA on accuracy in Experiment 5

	Accuracy				*RTs*			
	df	*F*	*p*	*ηp²*	*df*	*F*	*p*	*ηp²*
Configuration	1, 68	14.17	< .001	0.34	1, 68	3.46	.067	0.12
Eccentricity	1, 68	14.96	< .001	0.58	1, 68	0.49	.486	0.01
Set size	1, 68	52.71	< .001	0.43	1, 68	0.17	.678	0.00
Type	1, 68	214.68	< .001	0.96	1, 68	7.53	.008	0.50
Configuration x Eccentricity	1, 68	4.23	.043	0.10	1, 68	0.02	.883	0.00
Configuration x Set size	1, 68	0.62	.433	0.01	1, 68	1.58	.213	0.03
Configuration x Type	1, 68	8.47	.005	0.24	1, 68	2.34	.131	0.10
Eccentricity x Set size	1, 68	8.94	.004	0.09	1, 68	0.79	.376	0.00
Eccentricity x Type	1, 68	11.11	.001	0.35	1, 68	0.41	.524	0.00
Set size x Type	1, 68	32.58	< .001	0.30	1, 68	0.16	.688	0.00
Configuration x Eccentricity x Type	1, 68	0.66	.418	0.02	1, 68	2.19	0.143	0.04
Configuration x Eccentricity x Set size	1, 68	0.00	.946	0.00	1, 68	1.63	.206	0.02
Configuration x Set size x Type	1, 68	0.00	.945	0.00	1, 68	1.67	.201	0.01
Eccentricity x Set size x Type	1, 68	0.11	.741	0.00	1, 68	0.81	.372	0.00
Configuration x Eccentricity x Set size x Type	1, 68	0.38	.541	0.01	1, 68	0.30	.586	0.00