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The Two-Body Inversion Effect

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Abstract
How does one perceive groups of people? It is known that functionally interacting objects (e.g., a glass and a pitcher tilted as if pouring water into it) are perceptually grouped. Here, we showed that processing of multiple human bodies is also influenced by their relative positioning. In a series of categorization experiments, bodies facing each other (seemingly interacting) were recognized more accurately than bodies facing away from each other (noninteracting). Moreover, recognition of facing body dyads (but not nonfacing body dyads) was strongly impaired when those stimuli were inverted, similar to what has been found for individual bodies. This inversion effect demonstrates sensitivity of the visual system to facing body dyads in their common upright configuration and might imply recruitment of configural processing (i.e., processing of the overall body configuration without prior part-by-part analysis). These findings suggest that facing dyads are represented as one structured unit, which may be the intermediate level of representation between multiple-object (body) perception and representation of social actions.

Keywords
face perception, object recognition, social perception, configural processing, scene perception

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In real-world scenes, people are often seen among other people. Yet current knowledge of person perception mostly relies on the study of visual perception of bodies in isolation. This research has demonstrated that bodies have a special status in the realm of objects. First, neuroimaging studies have identified brain areas in the occipitotemporal cortex specialized for processing bodies (Peelen & Downing, 2007) and faces (Kanwisher & Yovel, 2006). Second, behavioral findings suggest that the human perceptual and attentional systems are tuned to detecting conspecifics (Bonatti, Frot, Zangl, & Mehler, 2002; New, Cosmides, & Tooby, 2007; Stein, Sterzer, & Peelen, 2012). Third, body perception might be qualitatively different from perception of other objects. In particular, perceptual performance with images of individual bodies is disrupted, to a greater degree than performance with other objects, when body parts are scrambled or when bodies are inverted (Reed, Stone, Bozova, & Tanaka, 2003; Reed, Stone, Grubb, & McGoldrick, 2006). This *body-inversion effect* demonstrates sensitivity of the visual system to bodies in their common upright configuration and may imply that, for body recognition, the spatial arrangement of parts into a specific configuration is as important as (or more important than) the appearance of individual parts. Here, we addressed body perception in multiple-body scenarios, more akin to what the perceptual system must parse in real-world scenes. In particular, we addressed the visual processing of body dyads using backward masking.

Computational models (Green & Hummel, 2004), behavioral studies (Green & Hummel, 2006), and neuroimaging studies (Kaiser, Stein, & Peelen, 2014; Kim & Biederman, 2010; Roberts & Humphreys, 2010) have shown that sets of objects that function together in the

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service of a common goal or that have a common use can be perceptually grouped. For example, two objects (a pitcher and a glass) are processed more efficiently when they are shown as if they are interacting in a functional way (i.e., a pitcher tilted as if pouring water in a glass) than when presented in a nonfunctional configuration (i.e., a pitcher tilted as if pouring water away from the glass).

This strand of evidence suggests that the processing of body dyads might be driven by the relative positioning of the bodies, which can cue a functional relation (i.e., an interaction) or not. If dyads that are perceived as interacting are perceptually grouped (Green & Hummel, 2004; see also Alvarez, 2011), their processing could be more similar to the processing of one individual entity (i.e., one body), relative to the processing of two bodies perceived as unrelated.

In the current study, we used the relative positioning of two bodies in a dyad—facing with head-body orientation toward one another or facing away from one another—to manipulate the relation between them: interacting or noninteracting (Hafri, Papafragou, & Trueswell, 2013). We employed a *backward-masking* paradigm, in which the visibility of a target stimulus, presented for a short time, is reduced by a second stimulus (the mask) appearing at the same spatial location. The target stimulus on each trial was a pair of facing or nonfacing bodies or chairs (plants were used as fillers) in the upright canonical orientation or in an inverted orientation. Participants were asked to report whether they had seen bodies, chairs, or plants. We recorded response accuracy and reaction times (RTs) and measured the inversion effect to relate perceptual performance with body dyads to the well-known performance with individual bodies. Considering the inversion effect also allowed us to compare across categories, because lower-level physical properties (e.g., size, contrast, luminance), which may substantially differ across categories and strongly influence perceptual performance, are identical for upright and inverted stimuli. Furthermore, we addressed potential effects of task difficulty, meaningfulness of interaction, head versus body orientation, and intensity of implied motion on performance.

In four experiments, we found that facing dyads were perceived more efficiently than nonfacing dyads. Notably, the body-inversion effect was significantly stronger for facing than for nonfacing dyads, which demonstrates that the visual system is sensitive to facing dyads in their common upright position. The body-inversion effect may suggest that facing dyads, just like individual bodies, are processed as a structured unit, with great emphasis on the spatial relations among their component parts (Maurer, Le Grand, & Mondloch, 2002). Processing nonfacing dyads may rely more on an objectlike part-by-part perceptual analysis. The effect of positioning (facing vs. facing away) on the processing modality was specific to body dyads, which suggests that it was driven by the representation of functional, perhaps social, interactions among objects rather than mere physical orientation.

Experiment 1

We first investigated whether recognition performance for two bodies that appeared spatially close was affected by their relative positioning (facing or facing away from each other) and by their orientation (upright or inverted).

Method

Participants. Twenty healthy adults (age range = 18–30 years) participated in Experiment 1 as paid volunteers. All gave informed consent. Experiment 1 was exploratory with respect to the sample size. The key effect size of this experiment was used for power calculation and to determine the sample size in the subsequent experiments.

Stimuli and apparatus. All stimuli were gray-scale 3-D figures created with Daz3D (Daz Productions, Salt Lake City, UT) and the Image Processing Toolbox in MATLAB (The MathWorks, Natick, MA). For the facing condition, 30 upright body dyads were created by combining eight figures (and their mirrored images) in different poses seen from a lateral view. Poses were chosen so that the two halves of each figure contained an approximately equal number of pixels. To this end, poses with fully outstretched extremities were discarded. All poses were biomechanically possible. Thirty nonfacing dyads were created by swapping the two figures (i.e., the figure on the left side was moved to the right side and vice versa). Thus, facing and nonfacing dyads involved the very same figures and differed only in their relative positioning. The centers of the two minimal bounding boxes that contained each figure of the dyad overlapped with the centers of the hemi-displays. Therefore, across all dyads, the centers of the two figures were equally distant from each other and from the center of the display (1.8° of visual angle). In addition, we verified that the distance between the closest points of the two figures was comparable for facing and nonfacing dyads (1.22° and 1.24° of visual angle, respectively), $t(29) = 0.292$, $p > .250$. Great care was used in matching distances, as physical proximity may promote grouping. For each dyad, we created a flipped version, which yielded a total of 60 facing and 60 nonfacing upright dyads, which were then rotated 180° to obtain 120 inverted stimuli.

An identical approach was implemented to create pairs of chairs, using six exemplars (60 facing and 60 nonfacing dyads; mean distance from center: 2° of visual

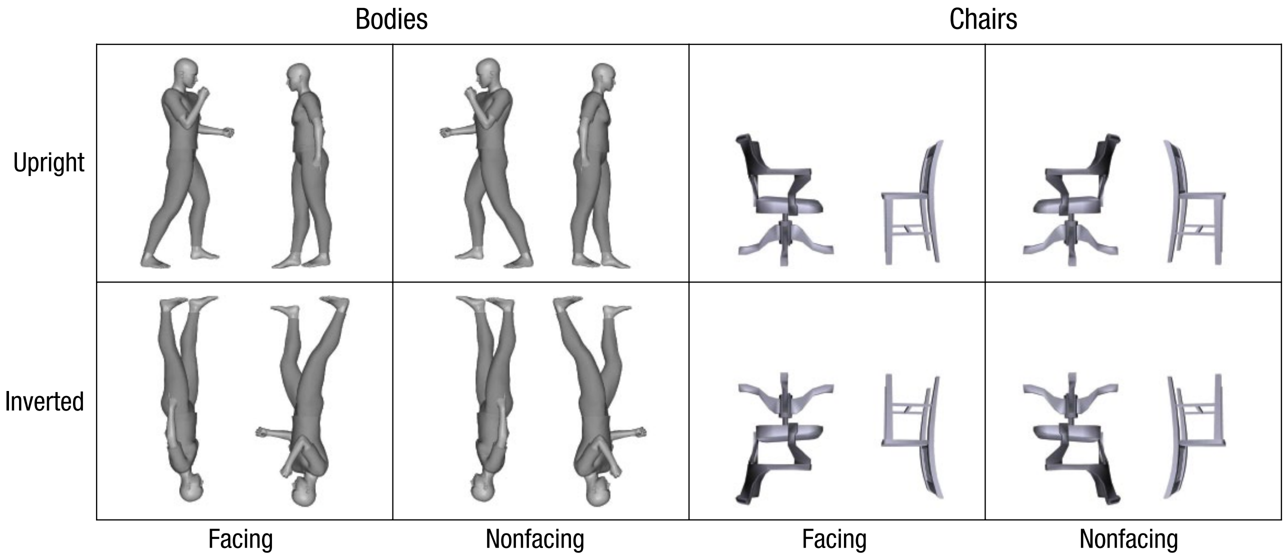

Fig. 1. Examples of experimental stimuli. On each trial, a pair of bodies, chairs, or plants (not pictured) was shown in an upright or inverted orientation. Members of body and chair dyads either faced each other or faced away from each other. (Note that in the actual experiments, stimuli were presented on a gray background.)

angle; mean distance between the two closest points: 1.64° of visual angle), and plants, using six exemplars (120 dyads; mean distance from center: 1.63° of visual angle; mean distance between the two closest points: 0.66° of visual angle). Note that plants cannot form facing and nonfacing pairs; therefore, they did not fit the current factorial design in terms of positioning. Plants were included as fillers for the purpose of inducing category processing of the stimuli of interest. In particular, with only two categories (bodies and chairs), participants might have solved the categorization task by looking for only one category (i.e., the easier to perceive). Indeed, a disparity in the ability to perceive bodies versus other object categories is often found (Reed et al., 2003; Stein et al., 2012). For example, if bodies were easier to detect, participants could have looked for the presence or absence of bodies only, responding "body" when seeing bodies and "chairs" when not seeing bodies. By adding plants, we prevented this strategy (if only bodies were processed, performance with chairs and plants would have been at chance) and ensured that participants recognized all the stimulus categories.

All stimuli subtended approximately 6° of visual angle and were shown on a gray background. Backward masks were high-contrast, contour-rich Mondrian-like images (11° × 10°) consisting of randomly arranged gray-scale circles (diameter = 0.4–1.8° of visual angle). Images were displayed on a 17-in. CRT monitor (1,024 × 768 pixel resolution, 85-Hz refresh rate) and viewed from a distance of 60 cm. Stimulus presentation and response collection were controlled with MATLAB using the Psychophysics Toolbox extensions (Brainard, 1997). Example stimuli are shown in Figure 1.

Procedure. Participants were seated on a chair in front of the monitor, with their eye level aligned with the center of the monitor. Their task was to report, in each trial, whether they had seen bodies, chairs, or plants (the three trial types were randomly interleaved). Each trial began with a blank screen (200 ms), followed by a central fixation cross (500 ms). Participants were instructed to fixate on the cross, which was placed where the target stimulus would appear. The cross was followed by a second blank screen (200 ms), and then the target stimulus was displayed (30 ms), followed by a mask (250 ms). After the offset of the mask, the screen remained blank until a response was given. The next trial began after a randomly chosen interval of 500, 750, or 1,000 ms. Participants were asked to respond as accurately and quickly as possible using a computer keyboard placed in front of them: They used their right index and middle finger to press "1" and "2," respectively, on the numeric keypad. Half the participants used "1" for "bodies" and "2" for "chairs," whereas the opposite mapping was used for the remaining participants. All pressed the space bar with their left index finger for "plants."

Accuracy and RTs were recorded. Every 30 trials, participants were invited to take a break. The task was divided in two blocks, each containing 30 trials for each of the 10 conditions (upright and inverted facing and nonfacing pairs of bodies and chairs, and upright and inverted pairs of plants), for a total of 360 trials per block.

Participants performed two familiarization blocks before the actual experiment. In the first familiarization block, which contained 48 trials (4 per each of the body and chair conditions plus 16 total for the plant conditions, randomly selected), target stimuli were shown for 250 ms, so the participants could see the stimuli clearly and become familiar with them. In the second familiarization block, which contained 96 trials (8 trials per each of the body and chair conditions plus 32 total for the plant conditions, randomly selected), target stimuli were shown for 30 ms, as in the actual experiment. At the end of the experiment, a subgroup of 18 participants completed a rating study, in which they judged, on 7-point Likert scales, the overall difficulty of the task and the difficulty specific to the detection of bodies, chairs, and plants (1 = *not difficult at all*, 7 = *extremely difficult*). The entire testing session lasted approximately 45 min.

Results

Trials with plants were not included in the analysis, as they served as fillers but did not satisfy the experimental manipulation of relative positioning (facing or facing away). The analyses were performed on the remaining 240 trials. For each participant, the mean proportion of correct responses (accuracy) and RT were computed for each condition. No participant performed below or above 2 standard deviations from the group accuracy mean; therefore, they were all included in the analysis. We focus here on participants' accuracy because it proved more sensitive than RTs to the masking manipulation with briefly presented targets (see the Supplemental Material available online for a full report of the RT results). RT results conformed to the pattern of accuracy results and excluded a speed/accuracy trade-off in participants' behavior.

A 2 (category: bodies, chairs) × 2 (positioning: facing, facing away) × 2 (orientation: upright, inverted) repeated measures analysis of variance (ANOVA) was conducted on accuracy rates. Most important, a significant three-way interaction among category, positioning, and orientation, $F(1, 19) = 15.75$, $p = .001$, $\eta_p^2 = .453$, showed that the inversion effect (the performance advantage with upright versus inverted stimuli) varied as a function of object category and relative positioning; it was most pronounced for facing body dyads, and it was not present for nonfacing body dyads (Fig. 2).

The analysis also showed an effect of category, $F(1, 19) = 13.36$, $p = .002$, with higher accuracy for bodies ($M = .86$, $SD = .09$) than chairs ($M = .81$, $SD = .11$), and an effect of inversion, $F(1, 19) = 9.83$, $p = .005$, which reflected significantly better performance with upright than inverted stimuli. There was also an interaction between category and positioning, $F(1, 19) = 33.81$, $p < .001$, which revealed that the difference in accuracy between facing and nonfacing dyads was larger for bodies than for chairs. Similarly, an interaction between category and inversion, $F(1, 19) = 5.75$, $p = .027$, showed that the inversion effect was also stronger for bodies than for chairs. Finally, an interaction between positioning and inversion, $F(1, 19) = 76.55$, $p < .001$, revealed that the inversion effect was stronger for facing than for nonfacing dyads. This pattern of results was fully replicated with the RT analysis (see the Supplemental Material).

Next, to follow up on the significant three-way interaction, we examined each category separately. We first ran a 2 (positioning) × 2 (orientation) repeated measures ANOVA on body trials, which revealed a main effect of positioning, $F(1, 19) = 6.36$, $p = .021$, a main effect of orientation, $F(1, 19) = 11.55$, $p = .003$, and a significant interaction between the two, $F(1, 19) = 56.68$, $p < .001$, $\eta_p^2 = .749$. The inversion effect was significant for facing dyads, $t(19) = 5.98$, $p < .001$, but not for nonfacing dyads, $t(19) = 0.31$, $p > .250$. Moreover, accuracy was higher for upright facing than for upright nonfacing dyads, $t(19) = 2.28$, $p = .034$. For chair trials, there was a main effect of positioning, $F(1, 19) = 19.96$, $p < .001$, due to an overall advantage of facing pairs over nonfacing pairs, and a trend for a main effect of orientation, $F(1, 19) = 3.92$, $p = .062$, but no interaction, $F(1, 19) = 2.21$, $p = .153$. Finally, analogously to performance for bodies, accuracy was higher for upright facing than for upright nonfacing pairs of chairs, $t(19) = 4.905$, $p < .001$.

Power calculation based on the key three-way interaction revealed that our statistical test was highly sensitive (power = 0.96). Therefore, the following experiments were run using a sample size comparable to that in Experiment 1.

In summary, we found an overall greater advantage for recognizing bodies and chairs in facing dyads than in nonfacing dyads. The effect of inversion, selective for facing body dyads, demonstrates a sensitivity of the visual system to the common upright configuration of seemingly interacting people. This effect further shows that facing and nonfacing body dyads are processed in distinct ways, with the recognition of facing dyads relying more on the overall spatial configuration of their component parts than on the parts themselves. One possibility is that information about the relative positioning of the two bodies is extracted before full perceptual analysis of the bodies. Then, depending on their positioning, the two bodies could be processed in a more or less configural way.

As expected, the inversion effect for chairs was minor and was not affected by the relative positioning of the two items in the pair. Finally, we observed an overall perceptual advantage for bodies over chairs in both accuracy and RTs (see the Supplemental Material). This effect

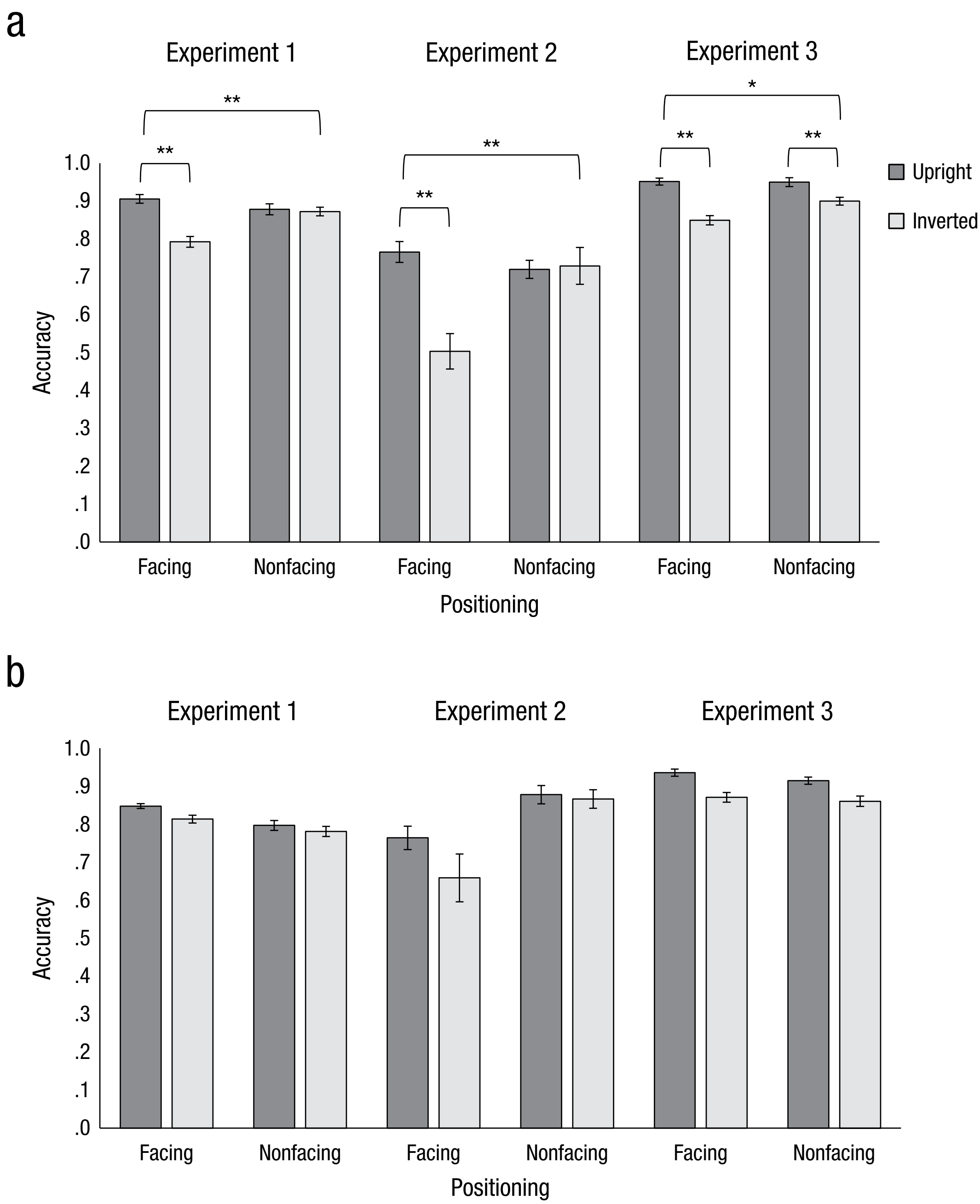

Fig. 2. Mean proportion of correct responses in Experiments 1 through 3 as a function of the positioning of the members of each dyad and their orientation, separately for (a) body trials and (b) chair trials. Error bars represent ±1 *SEM* within subjects (Cousineau, 2005). Asterisks indicate significant differences between stimulus groups (*p = .062, **$p < .01$).

was confirmed by the ratings in the postexperiment questionnaire, in which participants judged body recognition (M = 4.00, SD = 1.71) as easier than chair recognition (M = 4.89, SD = 1.41), $t(17)$ = 2.30, p = .034. Following this observation, in Experiment 2, we sought to rule out that a difference in task difficulty was responsible for the different patterns of results for bodies and chairs.

Experiment 2

In Experiment 2, we sought to replicate the results of Experiment 1 using a set of stimuli that were matched for recognition difficulty across categories. Moreover, because facing, but not nonfacing, dyads could depict meaningful interactions, we included a rating study to assess whether the meaningfulness of the interactions was related to participants' performance in the categorization task.

Method

Participants. Twenty-three healthy adults (age range = 18–30 years) participated in Experiment 2 as paid volunteers. All gave informed consent.

Stimuli and apparatus. To match body and nonbody stimuli for recognition difficulty, we reduced the contrast in body stimuli using the Image Processing Toolbox in MATLAB. All other parameters of the stimuli and apparatus were identical to those in Experiment 1.

Procedure. All procedures for the categorization task were the same as in Experiment 1. At the end of the experiment, a subgroup of 18 participants completed the same rating study used in Experiment 1. However, in this experiment, a subgroup of 11 participants completed an additional rating questionnaire in which they judged, on a 7-point Likert scale, the meaningfulness of the interactions in each of the 30 upright dyads of facing bodies. These dyads were the same as those used in the categorization task. In a prior pilot study, interactions in nonfacing dyads were judged to be meaningless; therefore, those dyads were not included. Participants had no time limit to respond. Participants were included in the two rating studies on the basis of whether or not they had time to complete them.

Results

Data from 2 participants were discarded, as their accuracy rates were more than 2 standard deviations below the group mean. The statistical approach was identical to that used in Experiment 1. A 2 × 2 × 2 repeated measures ANOVA on accuracy rates confirmed the key results of Experiment 1. A significant three-way interaction among category, positioning, and orientation, $F(1, 20) = 17.01$, $p = .001$, $\eta_p^2 = .460$, showed that the inversion effect was strongest for facing body dyads, while it was not present for nonfacing body dyads (Fig. 2). The analysis also showed an effect of category, $F(1, 20) = 9.83$, $p = .005$, this time because of higher accuracy with chairs ($M = .79$, $SD = .27$) than bodies ($M = .68$, $SD = .27$), as a consequence of the decrease in contrast for the body stimuli. The effect of positioning, $F(1, 20) = 8.91$, $p = .007$, the effect of inversion, $F(1, 20) = 8.53$, $p = .008$, and the interaction between positioning and inversion, $F(1, 20) = 8.04$, $p = .010$, were also significant. The interactions between category and positioning, $F(1, 20) = 3.16$, $p = .090$, and between category and inversion, $F(1, 20) = 3.06$, $p = .096$, did not approach significance.

Following up on the significant three-way interaction, we conducted a 2 × 2 ANOVA on body trials that revealed an effect of positioning, $F(1, 20) = 7.16$, $p = .015$, an effect of orientation, $F(1, 20) = 8.38$, $p = .009$, and a significant interaction between the two, $F(1, 20) = 11.77$, $p = .003$, $\eta_p^2 = .370$. As in Experiment 1, the cost of inversion was significant for facing dyads, $t(20) = 4.06$, $p < .001$, but not for nonfacing dyads, $t(20) = 0.17$, $p > .250$. Moreover, there was an advantage in the recognition of upright facing over upright nonfacing dyads, $t(19) = 2.16$, $p = .042$. The 2 × 2 ANOVA on chair trials revealed only a significant main effect of positioning, $F(1, 20) = 8.09$, $p = .010$, which revealed higher accuracy for nonfacing dyads than for facing dyads; there was a trend for a main effect of orientation, $F(1, 20) = 4.01$, $p < .059$, but no interaction, $F(1, 20) = 2.97$, $p = .100$.

Thus, the pattern of results of Experiment 2 was consistent with the results of Experiment 1, in that participants were better at recognizing bodies in facing dyads than in nonfacing dyads. In addition, there was an inversion effect for dyads, but only when bodies faced each other. When bodies faced away from each other, the inversion effect was abolished, which suggests that participants had greater reliance on a part-based than a configural analysis of the stimuli. As in Experiment 1, the inversion effect for chairs was nearly significant but was not modulated by relative positioning (facing vs. facing away). Differently from Experiment 1, upright facing chairs were recognized no better than upright nonfacing chairs.

In sum, Experiment 2 replicated the key results of Experiment 1 in a setting in which recognition of bodies was at least as difficult as recognition of chairs. This circumstance is supported by objective measurements of accuracy during the experimental task (greater for chairs than for bodies), as well as by participants' postexperiment subjective-difficulty ratings, which did not show a reliable difference in perceived task difficulty between bodies and chairs, $t(17) = 1.57$, $p = .135$. An ANOVA on ratings with experiment (1, 2) as a between-subjects factor confirmed that the difference in perceived task difficulty was specific to Experiment 1—category-by-group interaction: $F(1, 34) = 7.03$, $p = .012$.

Finally, participants' ratings about the meaningfulness of interactions in facing dyads showed no correlation with objective measures of performance in the categorization task, as illustrated by Pearson's correlations with accuracy, $r = -.251$, n.s.; RTs, $r = -.176$, n.s.; and size of the inversion effect, $r = -.259$, n.s. This observation was confirmed in an additional analysis, in which we found no difference (all ps > .05) when comparing accuracy, RTs, and the inversion effect between the items falling in

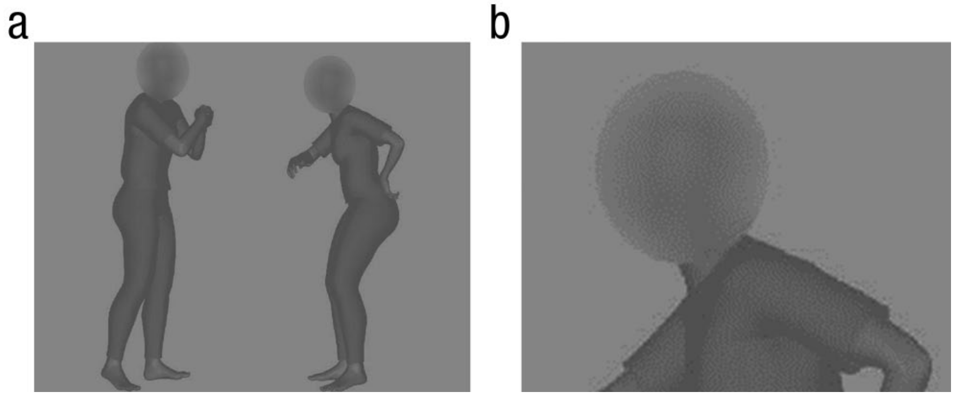

Fig. 3. Example of body stimuli in Experiment 3, in which the head areas were blurred. The illustrations show (a) the whole stimulus and (b) a detail of the head area.

the lower (n = 9) and higher (n = 7) quartiles of the meaningfulness distribution (obtained from the z-transformed scores of the meaningfulness ratings). In sum, we found no indication of a relationship between the meaningfulness of dyadic interactions and body recognition during the categorization task.

Although the null effect of stimulus meaningfulness cannot be conclusive, it speaks against the possibility that the performance difference between facing and nonfacing body dyads was mediated by a difference in the meaningfulness of the interactions. Yet this lack of sensitivity to the meaningfulness of interaction might raise the possibility that the body poses played no role at all in the facing-versus-nonfacing effect and that the effect was driven solely by the heads' position (i.e., the effect of facing vs. facing away would be, in fact, the effect of looking toward vs. looking away). We addressed this possibility in Experiment 3.

Experiment 3

It has been shown that the head is processed with higher priority relative to the rest of the body, both when encoding another person's direction of attention (Perrett & Emery, 1994) and discriminating individual body postures (Brandman & Yovel, 2010; Yovel, Pelc, & Lubetzky, 2010). In Experiment 3, we investigated the relative contribution of head positioning versus rest-of-the-body positioning in mediating the body-inversion effect for facing versus nonfacing dyads. We used the same task as before, the only difference being that the head direction was not visible.

Method

Participants. Twenty-two healthy adults (age range = 18–30 years) participated as paid volunteers. All provided informed consent.

Stimuli and apparatus. The stimuli and apparatus were identical to those in Experiment 1, except that information about head positioning in the body dyads (looking toward vs. looking away) was eliminated by blurring the heads with the Gaussian blurring function of the MATLAB Image Processing Toolbox (see Fig. 3).

Procedure. All procedures were identical to those in Experiment 1. At the end of the experiment, all 21 participants rated the perceived task difficulty using the same rating scale as in the previous experiments.

Results

Data from 1 participant were discarded, as his accuracy rate was more than 2 standard deviations below the group mean. The statistical approach was identical to that used in Experiment 1. A 2 × 2 × 2 repeated measures ANOVA on accuracy rates yielded a nearly significant trend for the three-way interaction among category, positioning, and orientation, $F(1, 20) = 3.92$, $p = .062$, $\eta_p^2 = .164$ (Fig. 2). As in Experiments 1 and 2, the inversion effect was strongest for facing body dyads. The analysis also showed a main effect of orientation, $F(1, 20) = 23.28$, $p < .001$, an interaction between category and positioning, $F(1, 20) = 10.69$, $p = .004$, and an interaction between positioning and orientation, $F(1, 20) = 5.62$, $p = .028$.

The 2 × 2 ANOVA on body trials revealed, once more, an effect of positioning, $F(1, 20) = 5.21$, $p = .034$, an effect of orientation, $F(1, 20) = 26.39$, $p < .001$, and, critically, an interaction between the two, $F(1, 20) = 8.53$, $p = .008$, $\eta_p^2 = .299$. The interaction indicated that although the inversion effect was statistically significant for both facing dyads, $t(20) = 5.05$, $p < .001$, and nonfacing dyads, $t(20) = 3.62$, $p = .002$, it was significantly stronger for the former. Moreover, and differently from Experiments 1 and 2, we did not find an advantage in the recognition of upright facing over nonfacing body dyads, $t(20) = 0.28$, $p > .250$. The ANOVA on chair trials revealed an effect of orientation, $F(1, 20) = 12.89$, $p = .002$, which reflected an overall advantage for upright over inverted dyads. The effect of positioning was nearly significant, $F(1, 20) = 3.75$, $p = .067$, but the interaction was not, $F(1, 20) < 1.00$.

The inversion effect for bodies with blurred head areas in our categorization task is consistent with inversion effects reported for headless bodies in tasks such as body detection (Stein et al., 2012) and person-identity recognition (Robbins & Coltheart, 2012). However, in other tasks, such as posture discrimination, no inversion effect was found for headless bodies (Minnebusch, Suchan, & Daum, 2009; Yovel et al., 2010), which suggests that the head and the rest of the body make different contributions, depending on the specific task demand.

More important, the pattern of results of Experiment 3 was consistent with the results of Experiments 1 and 2, in that there was a stronger inversion effect for facing than nonfacing body dyads. At the same time, some of the results from Experiment 3 differed from those in Experiments 1 and 2. First, there was no advantage in the recognition of upright facing over nonfacing dyads of bodies. Second, the inversion effect for nonfacing dyads was significantly less than for facing dyads, but it did not disappear.

We assessed whether the difference between Experiments 1 and 3 was statistically reliable using a four-way ANOVA with experiment (1, 3) as an additional between-subjects factor. We found no significant interaction among experiment, category, positioning, and orientation, $F(1, 39) = 1.31$, $p > .250$. Thus, the overall pattern of results with the strongest inversion effect for facing dyads was preserved even after information about head direction was unavailable in the stimuli (because of blurring). Furthermore, two pairwise *t* tests were used to compare the size of the inversion effect (performance with upright stimuli minus performance with inverted stimuli) for facing and for nonfacing dyads in Experiment 1 versus Experiment 3. The results showed that the inversion effect was comparable for facing body dyads in Experiments 1 and 3, $t(39) < 1$, n.s.; however, there was a trend for a difference in the inversion effect for nonfacing body dyads between the two experiments, with a larger inversion effect in Experiment 3 than in Experiment 1, $t(39) = 1.86$, $p = .070$. Finally, despite the bodies' blurred heads, participants in Experiment 3, just like in Experiment 1, rated bodies as significantly easier to recognize than chairs, $t(20) = 2.48$, $p = .022$.

Experiment 4

Motion implied in static images of human bodies may affect how they are processed (Kourtzi & Kanwisher, 2000). We collected subjective reports of the perceived intensity of implied motion for each dyad (and for each body individually) to test whether facing and nonfacing dyads significantly differed in this respect.

Method

Participants. Twenty-four healthy adults (age range = 18–35 years) volunteered for this experiment. All gave informed consent.

Stimuli and apparatus. Initial stimuli were the same eight single figures as in previous experiments plus two new figures, seen both in leftward and rightward lateral view, which yielded a total of 20 single figures. Using the same procedures as in Experiment 1, we created 55 facing dyads, whose positions were then swapped to make 55 nonfacing dyads. Those 110 dyads and the 20 single figures were the stimuli in Experiment 4.

Procedure. Subjective reports of the perceived intensity of implied motion in the experimental stimuli were made using 9-point Likert scales, completed online through the Testable Web site (www.testable.org). Participants were instructed to sit approximately 50 cm away from the computer screen. Before starting the experiment, they were prompted to enter their age, native language, and gender (optional). They were instructed to fixate the center of the screen, where stimuli appeared, one at a time, for 1,000 ms each. Every stimulus was followed by a screen showing a number line from 1 (left) to 9 (right), with the labels "static" and "extremely dynamic" at the left and right extremes of the line, respectively. Participants had to rate how much each stimulus, as a whole, gave an impression of movement and dynamics. They were given no time limit in which to respond. After responding by pressing one of the numbers from 1 to 9 on the computer keyboard, they had to click the "NEXT" button at the bottom of the screen to continue. The next trial began after 500 ms. Stimuli from three experimental conditions (single body, facing body dyads, nonfacing body dyads) were shown randomly. Participants saw three example trials before starting the actual rating trials.

Results

Participants' ratings were entered into an ANOVA with stimulus type (single body, facing body dyads, nonfacing body dyads) as the only within-subjects factor, which turned out to be significant, $F(2, 46) = 59.15$, $p < .001$. Pairwise comparisons showed no difference in perceived intensity of implied motion for facing and nonfacing dyads, $t(23) = 1.32$, $p = .199$. Higher intensities of implied motion were assigned to both facing dyads ($M = 5.05$, $SD = 1.48$) and nonfacing dyads ($M = 4.91$, $SD = 1.31$) than to single bodies ($M = 3.88$, $SD = 1.42$)—single versus facing: $t(23) = 8.41$, $p < .001$; single versus facing away, $t(23) = 10.33$, $p < .001$. Thus, the relative positioning of dyad members did not affect the perceived intensity of implied motion, which in both cases was significantly greater than the implied motion perceived in single figures. This outcome rules out a role of implied motion in the differential processing of facing and nonfacing dyads.

The RT analysis revealed a possibly relevant (as well as unexpected) result: The time that participants spent to make judgments about implied motion for facing dyads was comparable with the time they spent on single figures, and RTs in both these conditions were significantly faster than in nonfacing trials. This observation was supported by tests performed on RTs after we discarded values more than 2 standard deviations away from the individual condition mean (4.6%). This analysis showed a main effect of stimulus type, $F(2, 46) = 5.44$, $p = .008$, which was driven by slower RTs for nonfacing dyads ($M = 2{,}230.44$ ms, $SD = 798.82$) than for facing dyads ($M = 2{,}139.11$ ms, $SD = 731.82$), $t(23) = 2.36$, $p = .027$, and slower RTs for nonfacing dyads than for single bodies ($M = 2{,}035.44$ ms, $SD = 712.71$), $t(23) = 2.70$, $p = .013$. RTs for facing dyads and single bodies did not differ significantly, $t(23) = 1.68$, $p = .106$. This observation suggests that two bodies facing each other as if interacting form an integrated unit and, therefore, are processed more similarly to one body than to two bodies perceived as distinct, unrelated units.

General Discussion

The current research was conceived to study how multiple bodies are processed and whether they can form functional units. The relative positioning of two bodies was used to cue the impression that they were interacting (facing body dyads) or not interacting (nonfacing body dyads). This choice was motivated by evidence that the relative positioning of objects affects how they are perceived (Green & Hummel, 2006; Kaiser et al., 2014), and in person perception, gaze, head, and body direction is a critical cue of shared attention and social interaction (Gobbini, Gors, Halchenko, Hughes, & Cipolli, 2013; Hafri et al., 2013; Kingstone, 2009; Langton, Watt, & Bruce, 2000). In three experiments, we found that dyads of facing bodies elicited a strong inversion effect, whereas this effect was critically attenuated or abolished when the same two figures faced away from one another. Moreover, participants showed an overall advantage in the recognition of upright facing over nonfacing body dyads.

The latter result is in keeping with the idea that the human perceptual system is tuned to socially relevant stimuli (New et al., 2007; Stein et al., 2012). It is also consistent with the perceptual benefit found for pairs of familiar objects presented in a configuration that is functional to a common goal or use (Green & Hummel, 2006; Kaiser et al., 2014), which extends these findings to the category of human bodies. Just like a pitcher with its spout leaning toward a glass, two facing bodies would be perceptually grouped by virtue of the joint action that they are engaged in. By contrast, positioning affected performance with chairs only inconsistently, which indicates that the effect of positioning is driven by the representation of functional interactions among objects, rather than their mere physical orientations.

The body-inversion effect was selective for facing dyads, which demonstrates that the visual system is highly sensitive to grouped bodies presented in their common upright positions. This sensitivity may imply a role for configural processing, that is, the processing of the stimulus as a unitary, structured configuration, in which the specific spatial relations among parts are at least as important for recognition as the appearance of the individual parts (Maurer et al., 2002). Configural processing applies to highly familiar object classes, such as faces and possibly bodies, whose members share a prototypical configuration (Diamond & Carey, 1986; Gauthier, Williams, Tarr, & Tanaka, 1998). While the inversion effect by itself cannot be taken as direct evidence of configural processing, it can be regarded as reflecting the strength of the perceiver's internal representation of an object class in its common (i.e., upright) orientation. This view has been applied, for instance, to account for the difference between processing of bodies and scrambled bodies (e.g., arms attached to the lower half of the trunk and legs to the upper half), for which the body-inversion effect does not occur (Reed et al., 2003). In the same vein, a facing dyad would match the internal representation of two spatially close bodies better than a nonfacing dyad, in which the prototypical, regular, and expected configuration is broken, which thus reduces or abolishes the cost of inversion.

Notably, when the heads were blurred so that information about their direction was unavailable (Experiment 3), facing and nonfacing dyads were processed more similarly to one another than in previous experiments: There was no advantage for facing over nonfacing dyads, and the inversion effect also occurred for nonfacing dyads, although to a lesser degree. This suggests that in two-body scenarios, the heads might be processed before the rest of the body. If the head does not provide information about positioning, spatial proximity may evoke a default grouped representation of two bodies. This would initiate configural processing and would abolish the advantage for facing over nonfacing dyads. Only subsequently, when one processes the rest of the body, would nonfacing dyads violate the expected configuration, thus interrupting the configural analysis (hence, reducing the inversion effect). Thus, without information about the head direction, the positioning of the bodies on its own can act as a cue to trigger different processing for facing and nonfacing dyads.

In addition to providing insight into the relative contribution of heads and bodies in multiple-body processing, the results of Experiment 3 support the hypothesis that the default, regular, or expected configuration for two spatially close bodies is the one in which they face each other. When facing, two bodies form a functional unit, because their gaze, head, and body direction is a critical cue of interaction, which is a promoter of perceptual grouping (Green & Hummel, 2006; see also Riddoch, Humphreys, Edwards, Baker, & Willson, 2003). The view of a facing dyad as a functional unit is further encouraged by the results of Experiment 4, in which processing times were comparable for facing dyads and single bodies, although facing and nonfacing dyads depicted two identical body poses at equal distance and with matched intensities of implied motion.

Broadly speaking, the current results show that inversion can affect categorization of bodies. This extends the inversion effect observed in single-body detection (Stein et al., 2012) and discrimination tasks (Minnebusch et al., 2009; Yovel et al., 2010), although effects of body inversion in different tasks might have different origins. Moreover, the demand to retrieve basic-level category information without instruction to attend to other aspects of the stimuli, during a short stimulus presentation interrupted by masking, suggests that relations among bodies are captured quite automatically, in a processing stage that precedes more elaborate, conscious recognition of body poses and actions. At this early processing level, the representation of facing dyads may be a perceptual proxy for action representation. Configural-processing mechanisms evoked by facing dyads may have a benefit for subsequent action recognition, driving the information process from multiple-body perception to social-action understanding. In fact, encoding body configurations is pivotal for action recognition, as demonstrated by humans' remarkable ability to identify actions from simplified point-light displays (i.e., depictions of body configurations without further visual attributes; Dittrich, Troscianko, Lea, & Morgan, 1996).

In conclusion, we have described a novel phenomenon that we call the *two-body inversion effect*, in which two bodies facing each other are recognized more easily than the same two bodies facing away from each other and are processed as a structured configuration, or functional unit. This configuration may identify the intermediate level of representation that drives perception of multiple bodies into the representation of complex social actions.

Action Editor

Alice J. O'Toole served as action editor for this article.

Author Contributions

L. Papeo developed the study concept. All authors contributed to the study design. Testing, data collection, and analysis were performed by L. Papeo. Data were interpreted by L. Papeo, T. Stein, and S. Soto-Faraco. L. Papeo drafted the manuscript, and S. Soto-Faraco and T. Stein provided critical revisions. All authors approved the final version of the manuscript for submission.

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The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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Supplemental Material

Additional supporting information can be found at http://journals.sagepub.com/doi/suppl/10.1177/0956797616685769

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