## Abstract

Faces and bodies are more difficult to perceive when presented inverted than when presented upright (i.e., stimulus inversion effect); an effect that has been attributed to the disruption of holistic processing. The features that can trigger holistic processing in faces and bodies, however, still remain elusive. In the current study, by using a sequential matching task, we tested whether stimulus inversion affects various categories of visual stimuli: faces, faceless heads, faceless heads in body context, headless bodies naked, whole bodies naked, headless bodies clothed, and whole bodies clothed. Both accuracy and inversion efficiency score (IES) results show inversion effects for all categories but for clothed bodies (with and without heads). In addition, the magnitude of the inversion effect for face, naked body and faceless heads was similar. Our findings demonstrate that the perception of faces, faceless heads and naked bodies relies on holistic processing. Clothed bodies (with and without heads), on the other side, may trigger clothes-sensitive rather than body-sensitive perceptual mechanisms.

## 1. Introduction

The human face is the most important stimulus for social interactions, as it conveys much information such as identity, race, gender, age, expression, gaze direction, approachability (Calder, 2011), and the majority of this information is accessed in few hundred milliseconds (Yamamoto & Kashikura, 2000; Rivolta, Palermo, Schmalzl, & Williams, 2011; Rivolta et al., 2014) thanks to dedicated neural structures (Kanwisher, 2010; Rivolta et al., 2014). It is believed that this exceptional ability relies on face-specific perceptual mechanisms termed *holistic*, that allow perceiving the face as a whole, and not just as the sum of the individual face features (Palermo et al., 2011; Rossion, 2008). The classic effect that (albeit indirectly) demonstrates the existence of holistic face processing is the "face-inversion effect" (FIE; Yin, 1969), which shows that faces are harder to perceive when shown upside-down than when in the canonical (i.e., upright) orientation. Since objects are much less affected by stimulus inversion, the FIE has been adopted as evidence to indicate that upright faces *only* are processed via holistic mechanisms (Kanwisher & Yovel, 2009; McKone & Yovel, 2009). Faces, however, do not represent the solely stimuli we rely upon for social interaction, since much information also comes from body perception. Interestingly, stimulus inversion has been shown to affect body perception in a comparable way (i.e., body inversion effect; BIE), thus suggesting that human bodies may also rely on holistic perceptual processing (Cox, Meyers & Sinha, 2004; de Gelder et al., 2010; Hills, Cooper & Pake, 2013; Reed, Stone, Bozova & Tanaka, 2003).

The stimuli and the tasks adopted in these studies are, however, quite heterogeneous. They can be broadly divided into tasks requiring to perceive/recognise body position (Brandman & Yovel, 2012), body emotions (Aviezer, Trope, &

Todorov, 2012), or body identity (Robbins & Coltheart, 2012). Some studies presented whole bodies (with heads) (Reed et al., 2003), whereas other presented headless bodies (Yovel, Pelc, & Lubetzky 2010). Finally, some studies presented bodies with clothes (Minnebusch, Suchan & Daum, 2009; Susilo et al., 2013; Willems, Vrancken, Germeys, & Verfaillie, 2014), whereas others presented bodies with minimal clothing (Reed, Stone, Grubb, & McGoldrick, 2006; Tao & Sun, 2013). All these manipulations might explain some of the heterogeneity seen in the literature. For instance, with a same/different, forced-choice, inversion paradigm, Reed et al. (2003) examined the inversion effects of faces, body positions (clothed stimuli with heads), and houses, and showed slower reaction times (RT) and higher error rates for the recognition of inverted compared to upright human bodies in which the head and the face were clearly visible. Moreover, the BIE was greater than the inversion effects for houses, and of similar magnitude to the FIE, thus suggesting the existence of holistic processing for body perception.

Some evidence, however, indicates that bodies without heads (i.e., which exclude the confounding factor of face processing in the context of a whole body) do not elicit a BIE (Minnebusch et al., 2009), which might be explained by the fact that information from the head/face is necessary to trigger holistic processing (Yovel et al., 2010). Additional evidence for the critical role of the head/face to trigger the BIE comes from Brandman and Yovel (2012), who presented participants with clothed stimuli only and reported a lack of BIE for headless bodies, and significant inversion effects for faces, whole bodies, and, surprisingly, for faceless heads with minimal (i.e., neck and shoulders) body context. This FIE for faceless heads with minimal body context is of particular interest since the FIE has long been attributed to the disruption of spatial relations of internal facial features in inverted relative to upright faces (Farah, Wilson, Drain & Tanaka, 1998; McKone & Yovel, 2009; Rossion, 2008). Taken together, these findings highlight the role of the head for holistic processing of bodies, and its importance for accurate body recognition (Brandman & Yovel, 2012; Minnebusch, et al., 2009; Yovel et al., 2010). Furthermore, the absence of inversion effects for headless bodies suggests that the BIE may actually be a reflection of face, and not body sensitive perceptual mechanisms (Brandman & Yovel, 2012).

In contrast with these findings, Robbins and Coltheart (2012) demonstrated headless bodies BIEs, (for both familiar and unfamiliar clothed bodies), thus, suggesting holistic mechanisms for these stimuli. Overall, these results indicate that, like the FIE which has long been associated with face-selective mechanisms (Mazard, Schiltz & Rossion, 2006), the BIE may be considered a specialized marker for the processing of its own stimulus (Robbins & Coltheart, 2012). The lack of BIE for headless bodies reported in previous literature (Minnebusch et al., 2009; Brandman & Yovel, 2012; Yovel et al., 2010) may be due to the stimuli used in such investigations; for instance, the stimuli employed by Robbins and Coltheart (2012) differed in identity only, whereas in Minnebusch et al. (2009) there were also differences in clothing, thus potentially engaging clothing processing rather than body-specific perception. Moreover, the absence of BIE for headless bodies may be due to the employment of posture-based approaches, in which all stimuli are of the same identity and differ in posture only. In contrast to identity-based approaches, where all stimuli differ in identity only, posture-based approaches may elicit the perception of movement (de Gelder et al., 2010), as dynamic stimuli are likely to contain information that is explicit to movement (Atkinson et al., 2004), thus potentially triggering a processing style that differs from that of identity (Robbins & Coltheart, 2012).

Taken together, the available evidence is heterogeneous and the conditions under which a BIE is shown need to be clarified. Specifically, in the current study we investigated (i) the role plaid by the head in the BIE, (ii) the importance of body cues in the inversion effect of faceless heads, and (iii) how clothing affects the BIE. This last point is particularly important since while it is the case that bodies are typically clothed in Western culture, holistic mechanisms might be better triggered by body parts such as nipples, torso shape, musculature, skin color.

## 2. Methods

### *2.1 Participants*

A total of 25 participants (17 females; mean age: 28 years, age range: 18-58) were recruited. Each participant had no history of neurological and/or psychiatric conditions, and had normal or correct-to-normal vision. The study received ethical approval from the University of East London Ethics Committee, and it conforms to The Code of Ethics of the World Medical Association (Declaration of Helsinki), printed in the British Medical Journal (18th July 1964).

### *2.2 Stimuli and task*

In the current 'body task' participants were shown with seven different categories of visual stimuli: faces, faceless heads, faceless heads with minimal body context, whole bodies with clothes, whole bodies, headless bodies with clothes and headless bodies. Stimuli were presented upright and inverted (Figure 1). Face stimuli were created using FACES software (IQ Biometrix, Inc., Kingwoods; Texas), as in previous investigations (Brandman & Yovel, 2012). A total of 18 different-face pairs that differed in the shape of the mouth, nose and eyes were included in the face stimuli. The body and head stimuli were created from grey-scale male figures generated with Poser Pro 2014 software (Smith Micro Inc., Aliso Viejo; California) as in previous investigations (e.g., Willems et al., 2014). The Poser figures comprised images of whole bodies with clothes, whole bodies, headless bodies with clothes, headless bodies, faceless heads with minimal body context, and faceless heads. Each set contained 18 images. All face and body stimuli maintained the same pose and differed in identity only. Faceless stimuli differed in the shape of the head and ears only. All clothed stimuli were presented with the same clothing.

Images produced with Poser Pro were edited with Photoshop CC software (Adobe Inc., San Jose; California). Specifically, to create headless bodies, the heads of whole body images were removed from the neck up. Conversely, body parts were removed from the neck down to produce faceless heads, and from the chest down to create faceless heads in minimal body context. To conceal facial features in faceless stimuli, faces of the Poser Pro stimuli were covered with a grey ellipsoid. To create inverted stimuli, we rotated images used in the upright trial by 180° (See Figure 1 for examples of stimuli adopted). Stimuli were presented within a 317 x 317 pixel square, or approximately $12.5^0$ of visual angle at the 60 cm viewing distance.

The experiment took place in a dimly lit room. Stimuli were presented using E-Prime (version 2.0 software; Psychological Software Tools, Pittsburgh, PA) and were shown on a 15-inch LCD Toshiba laptop running Windows 7 (resolution: 1366 x 768; refresh rate: 60 Hz). Stimuli were presented in randomized blocks of stimuli of the same category (specific instructions were shown before the beginning of each of the seven block). Presentation of blocks was counterbalanced so that different categories and orientations would appear at different times during the experiment. Each trial began with a fixation dot at the centre of the screen for 300 ms. The first stimulus appeared on the screen for 250 ms followed by a fixation dot of 300 ms. The second stimulus appeared and remained on the screen until a response was made (Figure 2). Participants were asked to answer as quickly and accurately as possible by pressing the 'z' key for same, and the 'm' key for different. Accuracy and RTs were recorded; additionally, Inverse Efficiency Scores (IES) were computed for each block as a measure of system efficiency (Bruyer & Brysbaert, 2011). Upright and inverted blocks were presented in a random order. Each participant completed a total of 504 trials (36 trials per category x 7 categories x 2 orientations).

*2.3 Data processing and analysis*

All analyses were conducted using SPSS Statistics software (IBM Corp. Released 2013, IBM SPSS Statistics for Windows, version 22.0. Ammonk, NY: IBM Corp). A 7 x 2 within-subjects ANOVA with the factors "category" (faces, headless bodies, whole bodies, faceless heads, faceless heads in body context, headless bodies clothed, whole bodies clothed), and "orientation" (upright and inverted). The magnitude of the inversion effects (upright - inverted) for the different categories was compared using a repeated measures ANOVA. Post-hoc comparisons, Bonferroni corrected, were carried out using paired samples *t*-tests. For each participant, accuracy was computed as the percentage (%) of correct trials in each condition. RTs of correct trials only were analysed and IES were computed as the ratio between RT and accuracy (RT/accuracy). To minimize the effect of extreme values, median RTs have been considered for the analysis.

## 3. Results

The accuracy analysis indicated a statistically significant main effect of category ($F$(6, 144) = 28.5, $p < .001$), and a statistically significant main effect of orientation ($F$(1, 24) = 56.96, $p < .001$), with upright stimuli (69.7%) processed more accurately than inverted (64.7%) stimuli. There also was a statistically significant interaction between category and orientation ($F$(6, 144) = 4.27, $p = .001$); and post-hoc comparisons (Bonferroni corrected) showed significant inversion effects for faces ($t$(23) =5.65, $p <$ .001), headless bodies ($t$(23) =3.43, $p = .002$), whole bodies ($t$(23) = 4.19, $p < .001$), faceless heads in body context ($t$(23) = 2.15, $p < .05$), and faceless heads ($t$(23) = 2.91, $p = .008$), but not for headless ($t$(23) = -.39, $p = .71$) or whole clothed bodies [$t$(23) = -.04, $p = .73$] (Figure 3A) (these accuracy results replicate previous behavioural data we collected using a Tobii Model T120 system, thus underlying the reproducibility of these effects; see Supplementary information section for more details). Accuracy scores analysis of the magnitude of the inversion effects showed a main effect ($F$(6, 144) = 4.27, $p = .001$); pairwise comparisons revealed differences between face and headless body clothed ($t$(24) = 4.25, $p = .006$), and between whole body naked and headless body clothed ($t$(24) = 3.54, $p < .05$) (Figure 4A).

RTs analysis showed a statistically significant main effect of orientation ($F$(1, 24) = 7.49, $p = .01$), but no main effect of category ($F$(3.14, 75.38) = .98, $p > .05$). A significant interaction was found between orientation and category ($F$(2.49, 59.76) = 4.08, $p = .01$); post-hoc comparisons showed a significant inversion effect for faces ($t$(23) =3.71, $p = .001$), faceless heads ($t$(23) =3.03, $p = .006$), faceless heads in body context ($t$(23) =3.74, $p = .001$) and whole bodies ($t$(23) =2.56, $p = .017$); no significant differences were found for headless clothed bodies ($t$(23) =.005, $p = .99$), headless bodies ($t$(23) =1.4, $p = .17$) and whole clothed bodies ($t$(23) =-1.09, $p = .28$)

(Figure 3B). RTs analysis of the magnitude of the inversion effects showed a main effect ($F(2.49, 59.76) = 4.08$, $p = .015$); pairwise comparisons revealed differences between face and headless body clothed ($t(24) = 3.49$, $p < .05$) (Figure 4B).

A significant effect of both orientation ($F(1, 24) = 11.98$, $p = .002$) and category ($F(2.67, 63.99) = 6.69$, $p = .001$) was found on IES. Additionally, a significant orientation x category interaction was observed ($F(2.27, 54.58) = 5.68$, $p = .004$). Post-hoc comparisons showed a significant difference on faces ($t(23) = 4.50$, $p <$ 001), faceless heads ($t(23) = 3.73$, $p = .001$), headless bodies ($t(23) = 2.88$, $p = .008$), heads in minimal body context ($t(23) = 3.67$, $p = .001$) and whole bodies ($t(23) =3.74$, $p = .001$); no significant differences were observed on headless clothed bodies ($t(23)$ =.-.09, $p = .93$) and whole clothed bodies ($t(23) = -1.31$, $p = .20$) (Figure 3C). IES analysis of the magnitude of the inversion effects showed a main effect ($F(2.27, 54.58) = 5.69$, $p = .004$); pairwise comparisons revealed a differences between headless body clothed and face ($t(24) = 3.65$, $p < .05$), head ($t(24)= 3.46$, $p < .05$), head in minimal body context ($t(24) = 3.48$, $p < .05$) and whole body ($t(24) = 3.61$, $p < .05$) (Figure 4C).

## 4. Discussion

The present study investigated holistic processing in faces and bodies as assessed using stimulus inversion (Yin, 1969). In agreement with previous findings (Brandman & Yovel, 2012; Reed at al., 2003, 2006; Robbins & Coltheart, 2012; Stekelenburg & Gelder, 2004) the recognition of faces, bodies and heads was significantly impaired by stimulus inversion. Specifically, our results showed better performance (both for accuracy and IES) for upright, relative to inverted faces, headless bodies with minimal clothing, whole bodies with minimal clothing, faceless heads in body context, and faceless heads. In contrast, no inversion effect was found for headless and whole bodies with clothes.

***Body perception with and without the head***

Our results demonstrate the existence of a BIE for (minimally clothed) bodies with and without the head. Previous evidence showed that *only* bodies presented with a face/head triggered a BIE (Brandman & Yovel, 2012; Minnebusch et al., 2009; Yovel et al., 2010; Susilo et al., 2013), and this has been interpreted as a FIE rather then a BIE (i.e., the body without the head did not lead to a BIE). This interpretation has also been received support by functional MRI (fMRI) evidence showing that the BIE is mediated by face-sensitive, and not body-sensitive, brain regions (Brandman & Yovel, 2010). More recent behavioural evidence, in line with our results, has however showed a BIE (albeit of smaller magnitude) for headless bodies, thus positing for body-specific holistic mechanisms (Arizpe, 2017; Robbins 2012; Susilo & Duchaine, 2013). Converging evidence comes from Susilo et al (2013) that have demonstrated in patients with acquired prosopagnosia (i.e., the impairment in recognizing people by their faces) the existence of body inversion effects (with and without heads), but not the face inversion effect. In summary, evidence from the inversion effect suggests that body perception is mediated by dedicated holistic mechanisms. In addition, body-specific holistic mechanisms have also been highlighted by different paradigms which are considered markers for holistic face perception, such as the composite task (i.e., aligned bodies are harder to discriminate than misaligned ones; Robbins & Coltheart, 2012) and the part-whole task (i.e., body parts are easier to recognise when presented in the context of a body than when presented in isolation; Seitz, 2002).

There are (at least) two possible explanations for the absence of BIE for headless bodies seen in previous studies: (i) the stimuli employed by Brandman and Yovel, (2012) and Yovel et al. (2010) differed in posture only, and posture vs. identity may engage different processing styles/neural activity (Urgesi, Candidi, Ionta and Aglioti, 2006); (ii) stimuli in Minnebusch et al. (2009) presented strong differences in clothing, thus indicating that this may have engaged clothing-specific perceptual mechanisms rather than holistic processing (Robbins & Coltheart, 2012). In conclusion, in agreement with previous findings we showed BIE for (minimally clothed) headed and headless unfamiliar bodies which support the existence of holistic processing for body perception.

***The role of clothing in the genesis of the BIE***

A new finding from our study is that minimally clothed bodies (with and without a head) *only* lead to a BIE. Previous research, on the other hand, did show inversion effects for clothed bodies (Arizpe et al., 2017; Barra, Senot and Auclair, 2017; Robbins & Coltheart, 2012). Despite speculative in nature, it is likely that divergences between the current and previous studies might be (at least partially) driven by methodological differences. To the best of our knowledge the current is the only study so far which directly compared naked and clothed stimuli in a within-subject experiment; Brandman & Yovel (2010), for instance, adopted a between-subject design (i.e., different participants were exposed to different conditions). It is thus possible that our design may have introduced a "confounding" effect since the perception of one category (e.g., naked bodies) may have affected perceptual strategies of other categories (e.g., clothed bodies). To test this hypothesis future studies should directly compare results from between- and within- subject designs.

### *Inversion effect: the roles of face and head*

It the current experiment we replicated the classic finding of FIE (Brandman & Yovel, 2012; Rivolta, Palermo, Schmalzl, & Williams, 2012; Yin, 1969), which has traditionally been attributed to a disruption in the processing of the relation of internal facial features (i.e., holistic processing) for inverted, relative to upright, faces (Calder, 2011; Young, Hellawell, & Hay, 1987; Rossion, 2008). This classic explanation is, however, hard to align with our and previous (Brandman and Yovel, 2012) behavioural findings of FIE for faceless stimuli in the body context. We also extend these findings by showing inversion effect for faceless heads without body context. Despite speculative in nature, this effect may be due a "top-down" process, where the 'mental imagery' of internal facial features (i.e., face detection), might have triggered face-selective cognitive and neural mechanisms and, thus, led to an inversion effect (Brandman & Yovel, 2012; O'Craven & Kanwisher, 2000). Alternatively, the inversion effect might have been caused by the perception of the contour, since previous evidence showed that stimulus inversion affects the perception of sequentially presented faces who differ in their contour but have the same internal features (Mondloch, Le Grand, & Maurer, 2002; Rivolta, Palermo, Schmalzl, & Williams, 2012). In other words, face-specific activity can be triggered even without a facial features if there is enough contextual information (i.e., the presence of a body and the presence of a head/contour).

Previous evidence suggested that the BIE might be driven by face/head processing since headless bodies showed no or weaker inversion effect (Brandman and Yovel, 2010; Pelc, Lubetzky and Yovel, 2010). Given that our "whole body stimuli" differed in facial identity, it is likely that the BIE (with minimal clothing stimuli) was driven by the face (i.e., bodies were ignored). However, we believe that this explanation is unlikely since if this was true, we would also have expected an inversion effect for clothed bodies with heads, which was not shown.

### *Conclusions and future directions*

Our results demonstrate that both faces and bodies rely on holistic perceptual mechanisms. This is strengthened by the finding that the magnitude of the FIE (~ 10%) is similar to the inversion effect shown for minimally clothed bodies (with and without heads). It is worth noting, however, that some previous investigations reported a face inversion effect of ~ 25% (McKone & Yovel, 2009), thus suggesting that with different face stimuli, we might have found different magnitudes of inversion effects for faces and bodies.

Furthermore, the presence of a body context is not necessary for the generation of a faceless head inversion effect, thus suggesting the potential involvement of top-down imagery mechanisms. To test whether similar of different holistic mechanisms mediate the inversion effects of the various visual categories, future studies should rely on causal inference as shown by associations/(double)dissociations in brain lesion patients, and/or on brain stimulation paradigms.

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## Figure legends

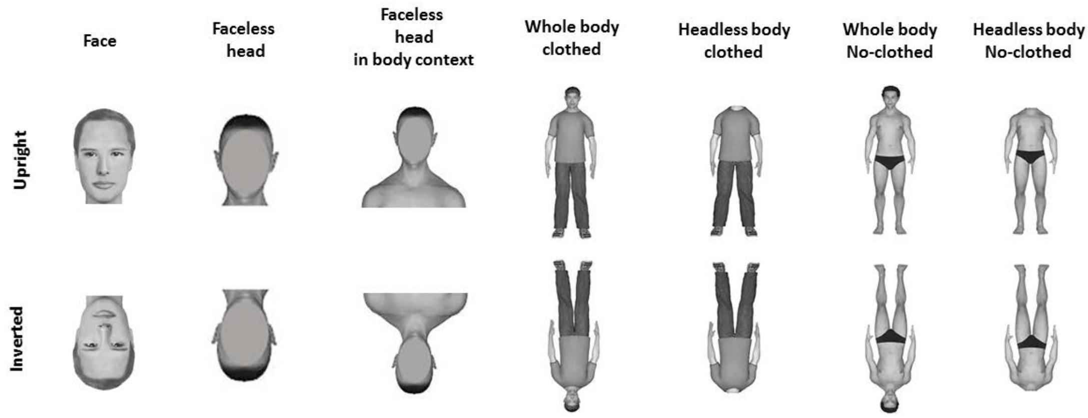


**Figure 1.** Examples of stimuli adopted in the seven categories of visual stimuli.

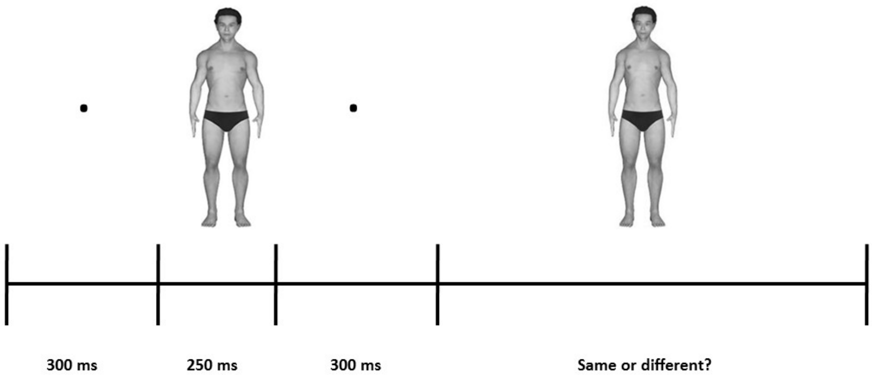


**Figure 2.** Trial structure in the example of two headed bodies with minimal clothing.

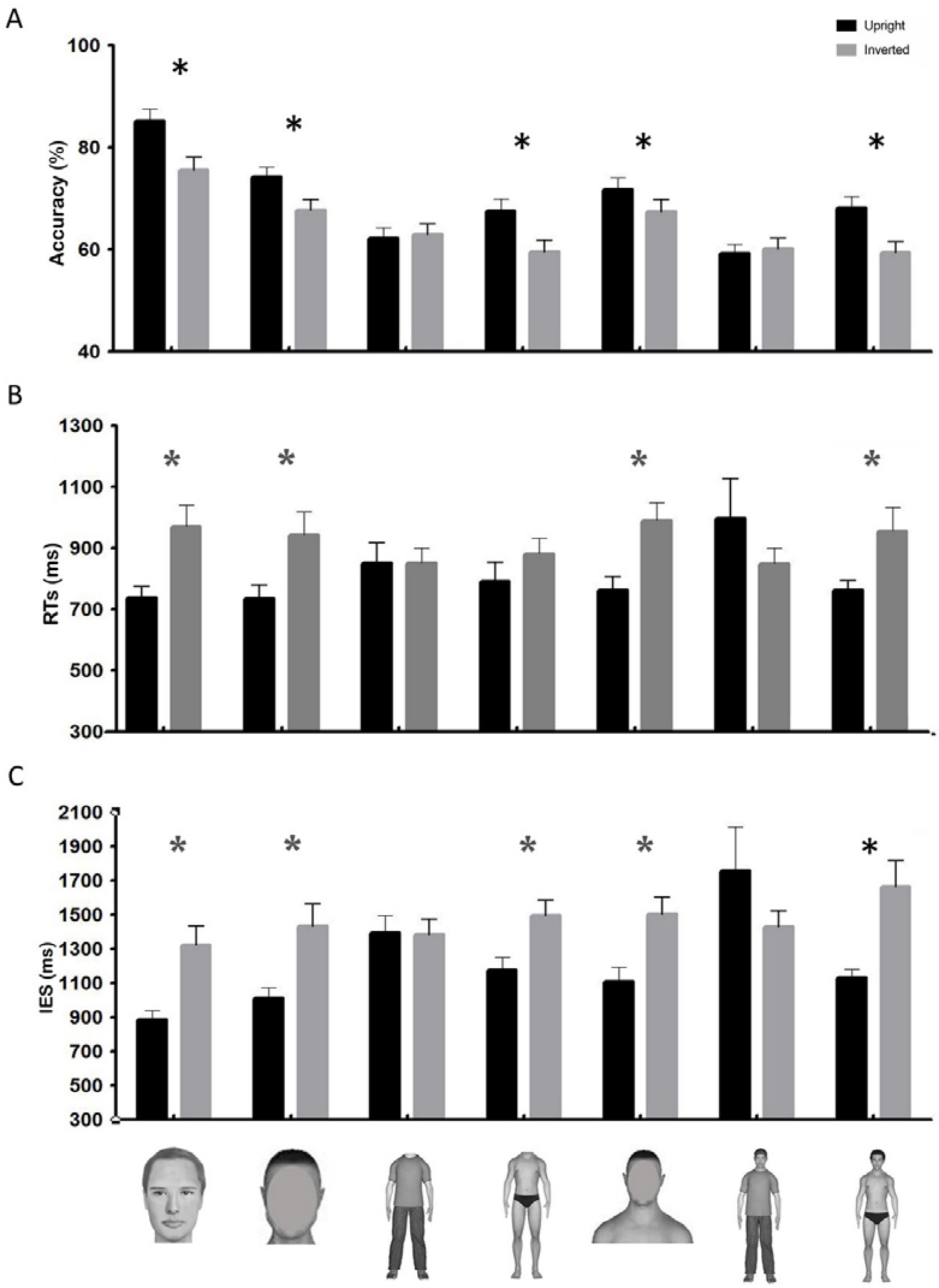


**Figure 3.** (A) Accuracy, (B) RTs and (C) IES results for upright (black) and inverted (grey) stimuli. Error bars denote SEM (* indicates a statistically significant difference; $p < .05$).

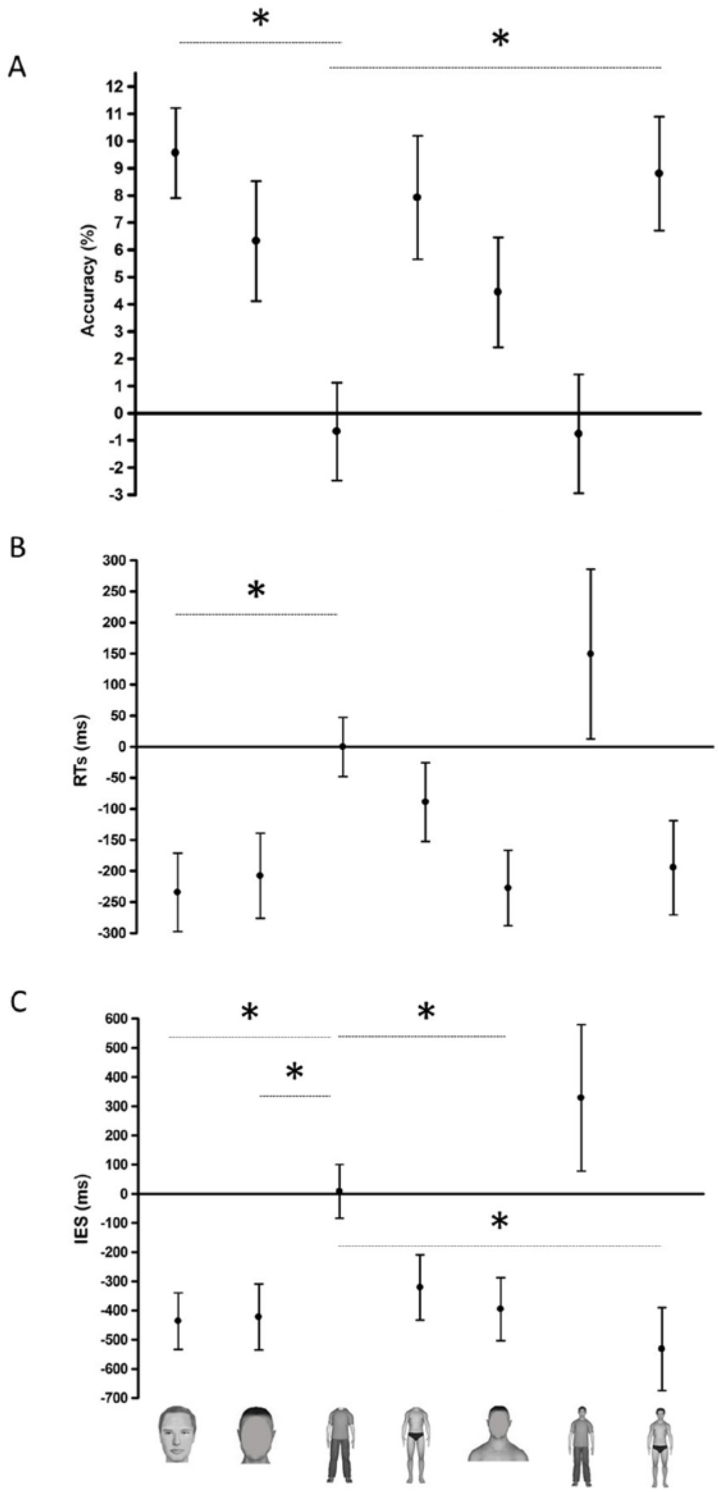


**Figure 4.** Inversion effects calculated for the seven categories. Results indicate (A) Accuracy, (B) RTs and (C) IES. Error bars denote SEM (* indicates a statistically significant difference; $p < .05$).

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