Dissecting the visual perception of body shape with the Garner selective attention paradigm

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Abstract

The visual appearance of bodies provides important social cues - how are they extracted? We studied two socially-relevant dimensions that are revealed in static body shape – sex and weight. Three experiments using the Garner selective-attention paradigm, in the first such application for body stimuli, found that when making sex judgements, body weight was successfully filtered; however, when judging weight, variation in sex could not be ignored. This asymmetric pattern was not due to differences in the perceptual salience of the dimensions. It suggests a parallel-contingent process where sex and weight are processed concurrently, and ongoing analysis of sex influences processing of weight. A priming experiment supported that view: verbal pre-cues to the sex of a body influenced categorisation of its weight, but weight cues did not influence sex categorisation. This architecture reflects relationships between the shape cues to body weight and sex that are present in the social environment.

Keywords: Body perception; Garner interference; sex; body weight; social vision

Introduction

The visual appearance of other people carries a wide variety of socially-relevant information (Adams, 2011). To date, much of the emphasis in the field of "social vision", which explores the nature of these signals and the neurocognitive mechanisms that exploit them, has been on the face. This has led to what is now a widely accepted "standard model" of face processing (Bruce & Young, 1986; Haxby, Hoffman & Gobbini, 2000) that has broadly held up as new methods and evidence are brought to bear (Young & Bruce, 2011; Calder & Young, 2005; Duchaine & Yovel, 2015).

Increasingly, however, attention has been drawn to the rich cues available in the appearance of the rest of the body – cues about sex, age, weight, identity, and emotion (Coulson, 2004; de Gelder et al., 2010; Aviezer, Trope, & Todorov, 2012a; Aviezer, Trope, & Todorov, 2012b; Rice, Phillips, Natu, An & O'Toole, 2013; de Gelder, 2016). Partly because bodies have much in common with faces in the kinds of signals they provide about other people, empirical and theoretical approaches to body perception have naturally tended to borrow heavily from face perception, and parallels have been drawn (e.g. Peelen & Downing, 2007; Minnebusch & Daum, 2009). On the other hand, the physical appearance and dynamic properties of faces and bodies are distinct, and they are not equally well-suited to conveying the full range of social signals. In general, we remain some distance from establishing a "standard model" of body perception that approaches the completeness of the face model. Therefore still more work is needed that focuses on how we perceive bodies.

An important aim of any perceptual model is to determine the extent to which different kinds of stimulus information are processed by shared or independent systems. For example, an important element of early models of face perception was the proposal that the processing of static and dynamic properties (such as identity and emotional expression, respectively) can be functionally independent of each other (Bruce & Young, 1986; Ellis, 1989; Young, 1998). This prediction provided the impetus for subsequent empirical work with neuropsychological patients and healthy participants, and a range of behavioural, imaging, and neurostimulation approaches, leading to a nuanced understanding of the ways in which processing of these important facial dimensions interacts or not (e.g. Bruce, Ellis, Gibling & Young, 1987; Calder & Young, 2005; Campbell, 1996; Humphreys, Donnelly, & Riddoch, 1993; Pitcher, Duchaine, & Walsh, 2014; Young, Newcombe, de Haan, Small, & Hay, 1993).

An influential proposal about the structure of body perception is that, in common to faces, different brain pathways process static and dynamic features of the body (e.g. Downing, Peelen, Wiggett, & Tew, 2006; Giese & Poggio, 2003; Vangeneugden et al., 2014). An important following question, then, is what is the structure of the static body representation? For example, is there is a single, unified representation of body shape that is shared with wider systems that draw further inferences from those properties (Downing & Peelen, 2011)? Or rather is there deeper structure within static body representations?

Here we approach this question with an experimental and conceptual approach developed by Garner (Algom & Fitousi, 2017; Garner, 1976; Pomerantz & Garner, 1973). Participants make judgements about one dimension of a stimulus, while variation on a second, task-irrelevant dimension is systematically manipulated. Specifically, in a typical Garner task, the irrelevant dimension remains stable during the *control* condition, whereas it varies across trials of the *orthogonal* condition. Successful filtering is indicated by similar mean response times (RTs) to the two conditions, and is taken to indicate separability of the channels processing the two stimulus dimensions. In contrast, if the RTs to judgements of the attended property are greater in the orthogonal condition than the control condition, this "Garner interference" is taken as an indicator that the two dimensions are analysed at least in part integrally - that is, via a shared process or representation.

Several studies have used the Garner method to examine how various dimensions of the face are processed, with some emphasis on comparing static and dynamic properties (for recent reviews see Algom and Fitousi, 2016; Lander and Butcher, 2015). For example, Garner tasks have been used to evaluate the independence or otherwise of sex and facial expression (Le Gal & Bruce, 2002), sex and identity (Ganel & Goshen-Gottstein, 2002), and identity and expression (Ganel & Goshen-Gottstein, 2004). An interesting pattern found in some studies, that is particularly relevant for the present findings, is an asymmetry in Garner interference. For example, Schweinberger, Burton, and Kelly (1999) evaluated the independence of identity and emotional expression in face perception (see also Schweinberger & Soukup, 1998; Atkinson, Tipples, Burt, & Young, 2005). Two groups of participants carried out either an identity categorisation task or an expression categorisation task (judging faces as angry or happy) on the same stimulus set of faces. Participants were generally able to selectively attend to identity without interference from the irrelevant facial expression information, but experienced Garner interference from identity when categorising expression. Such findings challenage both a straightforward separable or integral processing model.

In the present study, we used the Garner approach to examine the processing of static cues to two socially-relevant dimensions that are conveyed by variations in the shape of the body: *sex* and *weight*. Both sex and weight have high biological and socio-cultural relevance for observers -- for example, they inform judgments of health, attractiveness, and mating decisions (Barber, 1995; Dijkstra & Buunk, 2001; Furnham, Swami, & Shah, 2006; Singh, 1993, 1994; Singh & Young, 1995; Tovée, Edmonds, & Vuong, 2012). While body weight does change, it is stable over short time scales, and in that respect more like sex than (for example) fleeting emotional expressions. Furthermore, importantly for the present purposes, Tovée, Edmonds, & Vuong (2012) demonstrated through an attractiveness rating procedure that individuals tend to naturally perceive the continuum of body weight in two distinct categories, suggesting that a binary weight classification task can be meaningfully compared to a binary sex judgment task. In sum: an individual's body shape is influenced by their sex and by their weight, and Garner interference (or its absence) between judgments of these two traits will be revealing of the structure of the perceptual system that interprets the body's socially-relevant signals.

Experiment 1

Introduction

Participants in Experiment 1 performed binary weight or sex judgments either about human bodies, or, as a control, about geometric shapes. The body stimuli were computer-generated silhouettes (Fig. 1, top), which minimise confounds such as clothing and age. The geometric stimuli were constructed to be one of two different global shapes (to parallel the sex judgment on bodies) and also of two different aspect ratios (to parallel the weight judgment on bodies; Fig. 1, bottom). To avoid encouraging participants to make explicit comparisons between the body and the control stimuli (e.g. categorising one shape type as "male" and the other as "female"), different groups of participants made judgments of the two stimulus types.

We sought to ensure that aspects of the design did not implicitly direct participants' attention to the task-irrelevant features of the stimulus. For example, participants who performed one task (e.g. judging body weight while ignoring sex) might then, if asked to switch to a sex judgment task, continue to attend to body weight owing to a failure of task-switching. The resulting cost to performance would look like Garner interference but would be difficult to attribute to integral processing *per se*. Accordingly in Experiment 1, each participant performed only one task. Following similar logic, as a further measure to ensure that participants' attention was focused only on the task-relevant dimension, the control block was always presented before the orthogonal block, allowing for measurement of baseline RTs before variation in the irrelevant features potentially drew participants' attention to that dimension.

Methods

Participants

Participants were 64 undergraduate students at Bangor University, comprising 46 females, with a mean age of 20.14 years (range: 18-31). Participants took part in the experiment in return for course credit. All procedures were approved by the Ethics Committee of the School of Psychology at Bangor University.

Stimuli

Silhouettes of bodies (with heads cropped out) were generated using Poser Pro software application (Smith Micro Software, Inc.). All stimuli were 600 x 600 px and consisted of four large male bodies, four large female bodies, four slim male bodies, and four slim female bodies. Therefore eight large/slim and eight male/female images were tested. All bodies were positioned in a ‘T’ pose (Fig. 1). Geometric shape stimuli were generated using Microsoft® Powerpoint™. Again, stimuli were 600 x 600 px and consisted of four large and four slim inverted triangles, and four large and four slim hourglasses (Fig. 1). The inverted triangle and hourglass patterns were selected on the grounds that, while not appearing like bodies as such, they bear some abstract similarity to the typical torso shapes of men and women respectively.

Insert Figure 1 about here

Design and procedure

Half of the participants were tested with the body stimuli, and the other half with the shape stimuli. Two tasks were carried out: either a Sex task or a Weight task. The Sex task involved participants making a male/female sex judgement about a body stimulus, or a triangle/hourglass type judgement about a geometric shape stimulus. In the Weight task, participants made a categorical slim or large judgement about the bodies or the geometric shapes. The task-irrelevant dimension was not mentioned to participants. The between-participants design of this experiment means that 16 participants took part in each combination of the two tasks and the two stimulus types. Participants were assigned to one of these groups in a serial order, on the basis of order of registration for the study.

In each task, the trials were split into three blocks. There were 32 trials in each of the two control blocks, followed by 64 trials in the orthogonal block. This block structure was not made apparent to the participants, as the trials were presented in a series without a break. In the Sex task, body weight could be varied so that all bodies were slim for the first control block, then all large in the second block, and finally both slim and large in the orthogonal block. Likewise, in the Weight task, sex would vary in a similar way. The order in which the irrelevant variable was presented in the first two blocks was counterbalanced across participants. In the orthogonal blocks, each combination of levels of the task-relevant and task-irrelevant dimension was presented equally often, in a pseudorandom order determined uniquely for each participant.

The experiment was controlled by Psychtoolbox (Brainard, 1997) running in Matlab (MATLAB Release 2012b, The MathWorks, Inc., Natick, Massachusetts, US) on an Apple iMac computer. In each trial, a single stimulus was presented at the centre of the screen for either 1.5 sec or until the participant made a key-press response, whichever was shorter. Responses were recorded with the “f” and “j” keyboard keys. Participants were reminded of the response mapping with the corresponding category names ("large"/"slim" for the Weight task; either "male"/"female" or "hourglass"/"triangle" for the Sex task) printed at the bottom left and right of the display. Participants were instructed to respond as quickly and as accurately as possible. Viewing distance was not controlled but was approximately 60 cm on average.

Results

Data from three participants were excluded from analysis due to poor accuracy (<2.5 SD below the group mean), after which new participants were tested in order to make up the total N to 64.

Due to the pseudorandom way that the irrelevant dimension was varied in the orthogonal block, it was possible for that property to remain stable across several trials before the first exemplar of the alternative category was presented. For this reason, five trials were removed from the start of each orthogonal block before analysis.

Mean accuracy across all tasks and conditions was 91% correct. Accuracy data were submitted to a 2x2x2 mixed ANOVA with Stimulus (between participants; Body or Shape), Task (between participants; Weight or Sex), and Block (within participants; Control or Orthogonal) as factors. There was a significant main effect of Stimulus, $F(1, 60) = 8.2$, $p<0.01$, $\eta p^2 = 0.12$; more errors were made with body stimuli (M = 89.0%) than with shape stimuli (M=92.2%). There was a significant main effect of Task, $F(1, 60) = 5.9$, $p<0.05$, $\eta p^2 = 0.09$; more errors were made on the Weight task (M = 89.3%) than on the Sex task (M=91.9%). No other effects reached significance, all $F<2.1$, all $p>0.15$. Accuracy data for this and the other experiments are reported in Table 1.

Because accuracy was high, and because it was not strongly influenced by the interaction of task and stimulus variables, we focused our analyses on the response times for accurate trials (Fig. 2). These data were submitted to an ANOVA with the same design as the accuracy data. This analysis revealed significant main effects of all three variables: Stimulus: *F*(1,60)=54.4, $p<0.001$, $\eta p^2=0.48$; Task: *F*(1,60)=4.1, $p<0.05$, $\eta p^2=0.06$; and Block: *F*(1,60)=7.4, $p<0.01$, $\eta p^2=0.11$. These main effects were qualified by a significant interaction of all three variables, *F*(1,60)=4.1, $p<0.05$, $\eta p^2=0.06$.

Insert Figure 2 about here

To interpret this three-way interaction, performed two separate 2x2 analyses for groups performing the task with geometric shape stimuli or with body stimuli. For geometric shape stimuli, there were two significant main effects; Task: *F*(1,30)=7.3, $p<0.05$, $\eta p^2=0.20$; Block: *F*(1,30) = 9.1, $p<0.01$, $\eta p^2=0.23$. The interaction of these factors did not approach significance ($F<1$). That is, the size of the Garner interference effect (orthogonal blocks - control blocks) was not reliably modulated as a function of the task.

In contrast, the 2x2 ANOVA of the body stimulus conditions revealed no significant main effects (Task: *F*(1,30)=0.07, $p>0.05$, $\eta p^2=0.002$; and Block: *F*(1,30)=1.3, $p>0.05$, $\eta p^2=0.04$) but a significant interaction between these factors, *F*(1,30) = 4.4, $p<0.05$, $\eta p^2=0.13$. Within-task simple effects t-tests revealed that for the Sex task there was no significant Garner effect (M = -14 ms), *t*(15) = 0.58, $p>0.05$, $\eta p^2=0.02$, while there was a significant Garner effect for the Weight task (*M* = 49 ms), *t*(15) = 2.7, $p<0.05$, $\eta p^2=0.33$.

One possible account of the asymmetric Garner effect found for body stimuli is that the two tasks are not well-matched for general difficulty. In the extreme, if the perceptual discriminability of one dimension is strong while the other is minimal, then an asymmetric pattern of interference will arise for trivial reasons (Garner, 1983; Schweinberger et al., 1999). To address this possibility, we compared baseline performance for the control blocks of the two body tasks. Mean response times in the two tasks were comparable (Weight task: *M* = 654 ms; Sex task: 676 ms) and these did not differ significantly, *t*(30) = 0.64, $p > .05$, $\eta p^2= .014$.

Discussion

In a Garner selective attention paradigm performed on simple geometric shapes, we observed an interference effect such that RTs were slower under the orthogonal condition regardless of whether participants attended to shape type or size. The standard interpretation of such a result is that these two dimensions (at least for the types of stimuli tested here) are not processed fully independently. That is, attending to the shape of the image entails some selection of its size information, and vice versa.

In contrast, with simple body silhouettes participants experienced Garner interference when carrying out the weight task (and sex was irrelevant), but not when performing the sex task (when weight was irrelevant). Participants in the sex task actually showed a non-significant reduction in their RTs in the orthogonal condition. Because the control block always preceded the orthogonal block, it is likely that this reduction in RT is a practice effect: performance simply improved over time through practice, which was relatively unimpeded when variations in body weight were introduced.

The findings of the body task suggest that processing of weight and sex can be independent in one direction, but not in the other. Such asymmetries have been reported in other applications of the Garner task (see Algom and Fitousi, 2016; Garner, 1983) including in face perception (e.g. Schweinberger & Soukup 1998; Schweinberger et al., 1999). Before exploring an interpretation of the present asymmetry in detail, we sought to replicate and extend our findings in Experiments 2 and 3. In Experiment 1, the stimuli were not controlled for overall silhouette size. For example, the large body silhouettes had a more black pixels than the slim stimuli. It is difficult, therefore, to tease apart body-specific judgements pertaining to the weight and shape of a person from mere stimulus size judgements. To help control for this variation, in Experiment 2, a larger and a smaller version of each image was constructed. Additionally, we sought to generalise beyond the well-controlled but ecologically weak silhouette stimuli used in Experiment 1. To that end we used pictures of real people as stimuli instead of silhouettes.

In Experiment 3, our aim was to ensure that design aspects of Experiments 1 and 2 -- specifically the between-participants manipulation of task, and the fixed order of control and orthogonal blocks -- could not account for our findings. Therefore in Experiment 3, we replicated Experiment 2 with a within-participants design in which each participant performed both tasks and in which block order (control, orthogonal) was fully counterbalanced.

Experiment 2

Introduction

In Experiment 2, body stimuli comprising photographs of torsos were presented. Grey-scale images were used to remove any colour cues that correlate with sex. Clothing type was not controlled, however, allowing for a more realistic experience of perceiving a body. Further, a larger and a smaller version of each image was created, so that participants doing the weight task could not rely on the global size of the image on the screen to facilitate their response. Because there was no obvious control category that could be depicted photographically and that had dimensions that were comparable to sex and weight, in this experiment only body stimuli were included. Additionally, to increase power and generalizability, the number of trials was doubled, as was the number of body identities, relative to Experiment 1.

Methods

Participants

A new sample of 40 undergraduate students at Bangor University participated in return for course credit. These comprised 32 females, with a mean age of 20.01 (range: 18-46).

Stimuli

In order to control for stimulus size differences, all stimuli had a large (600 px height) and a small version (400 px height). Image width varied freely in order to maintain the original image aspect ratio. Heavy and slim images (identified as such by the authors' judgment) of males and females were obtained through internet searches. The images were greyscaled and cropped to exclude the head and lower legs. Pose was not controlled, although the arms were visible in all images and no unusual postures were included. Sixteen heavy and sixteen slim male and female images were collected, and a large and small version of each of these images was created, resulting in 128 stimuli. Examples are given in Figure 3.

Insert Figure 3 about here

Design and procedure

Half of the participants carried out the Weight task, while the other half completed the Sex task. For the Weight task, the categories were labelled for participants as 'heavy' and 'slim' to avoid the ambiguity of the word 'large' given that the images varied in size. Sixty-four trials were included in the first two blocks, and 128 in the final block. All other aspects of the design and procedure were the same as in Experiment 1.

Results

Data from 3 participants were excluded from analysis due to poor accuracy (<2.5 SD below the group mean), after which new participants were tested in order to make up the total N to 40. As in Experiment 1, five trials were removed from the start of the orthogonal blocks prior to analysis.

Mean accuracy across all tasks and conditions was 94% correct. Accuracy data were submitted to a 2x2 mixed-effects ANOVA with Task (between participants; Weight or Sex), and Block (within participants; Control or Orthogonal) as factors. Neither main effect nor the interaction were significant, all $F(1,38) < 1$. Accordingly, and in line with Experiment 1, our analyses focused on response time data for accurate trials.

A 2x2 mixed-effects ANOVA of mean RTs (Fig. 4) revealed a significant main effect of Task, $F(1,38) = 4.7$, $p < 0.05$, $\eta p^2 = 0.11$, but no significant main effect of Block type, $F(1,38) = 0.59$, $p > 0.05$, $\eta p^2 = 0.015$. The interaction of these variables was significant, $F(1,38) = 4.4$, $p < 0.05$, $\eta p^2 = 0.11$. Follow up T-tests revealed that in the Weight task, the Garner effect ($M = 47$ ms) was not significant, $t(19) = 1.5$, $p > 0.05$, $\eta p^2 = 0.11$. In contrast, a significant reversal of the Garner effect was revealed in the Sex task ($M = -22$ ms), $t(19) = 2.2$, $p < 0.05$, $\eta p^2 = 0.20$.

Insert Figure 4 about here

To address the possibility that differences in Garner interference revealed in the 2x2 interaction might be related to differences in overall difficulty between the tasks, we directly compared performance on the tasks in the control blocks. Mean response times in the control blocks were comparable (Weight task: M = 613 ms; Sex task: 597 ms) and these did not differ significantly, $t(38) = 0.67$, $p > 0.05$, $\eta p^2 = 0.012$.

Finally, to counter the loss of power resulting from between-participants designs, and to assess the evidence across Experiments 1 and 2, we performed a combined analysis focusing on the conditions common to both. We included data from Experiment 1 from those participants who performed the task on body stimuli, and data from all participants in Experiment 2. The RT data from accurate trials were submitted to a 2x2x2 mixed ANOVA with Experiment (1, 2) and Task (Weight, Sex) as between-participants variables and Block (Control, Orthogonal) as a within-participants variable. This analysis revealed a main effect of Experiment, $F(1,68)=10.4$, $p<.005$, $\eta p^2= 0.13$. However, this variable did not interact with the others, all $F<1.2$, $p>0.05$. Additionally there was an interaction of Task and Block, $F(1,68) = 8.6$, $p<0.01$, $\eta p^2= 0.11$, in the absence of significant main effects of either variable (Task: $F(1,68)=2.7$; Block: $F(1,68)=1.7$). Breaking down this interaction showed that in the Sex task there was no reliable Garner effect (M = -18 ms), $t(35) = 1.5$, $p>0.05$, $\eta p^2= 0.06$, but there was a reliable Garner effect in the Weight task (M = 48 ms), $t(35) = 2.5$, $p<0.05$, $\eta p^2= 0.16$.

Discussion

The results of Experiment 2 replicated those of Experiment 1 in finding again a significant interaction between task and block type. This asymmetry between tasks, we argue, is the most important overall finding arising from these two studies. Post-hoc t-tests did not show significant Garner interference in the Weight task (although the effect size was numerically similar to that in Experiment 1). However, this effect was robust when results were collapsed across both experiments. In contrast, the absence of Garner interference in the Sex task results was replicated.

Experiment 3

Introduction

Here we attempted to further generalise our findings across specific features of the design. In Experiments 1 and 2, task was manipulated between participants, reducing our power to compare tasks. Further, in those studies the control blocks always preceded the orthogonal blocks, meaning that practice effects could be confounded with our measures of Garner interference. Therefore in Experiment 3, all participants performed both tasks, and the order of blocks was fully counterbalanced across tasks and participants.

Methods

Participants

A new sample of 32 undergraduate students at the University of East Anglia participated in return for course credit. These comprised 25 females, with a mean age of 21.81 (range: 18-30).

Stimuli, design and procedure

The stimuli from Experiment 2 were used again for this study. All participants performed both tasks. Half of them performed the Sex task first, followed by the Weight task; the other half of participants performed the tasks in the opposite order. Orthogonally, we further counterbalanced across participants and independently for each task, whether they performed first the control block and then the orthogonal block, or vice versa. Additionally, the order of the control blocks was also balanced with respect to the level of the task-irrelevant dimension (e.g. first all male then all female, or *vice versa*, in the Weight task). All other aspects of the design and procedure were the same as in Experiment 2.

Results

It was not necessary to exclude any participants from analysis due to poor overall performance. As in the previous experiments, five trials were removed from the start of the orthogonal blocks prior to analysis.

Mean accuracy across all tasks and conditions was 91% correct. Accuracy data were submitted to a 2x2 within-participants ANOVA with Task (Weight or Sex), and Block (Control or Orthogonal) as factors. There was a significant main effect of Task, $F(1,31) = 128.8$, $p < 0.001$, $\eta p^2 = 0.81$, qualified by a significant interaction of Task by Block, $F(1,31) = 4.9$, $p < 0.05$, $\eta p^2 = 0.14$. In the Weight task, accuracy was higher for the Orthogonal blocks ($M = 93.9\%$ correct) than the Control blocks ($M = 93.1\%$)

whereas in the Sex task, Control performance ($M = 88.4\%$) was higher than in the Orthogonal task ($M = 87.5\%$). However in absolute terms these accuracy differences were small, and in neither task individually was the difference in accuracy between blocks statistically significant (Weight: $t(31) = 1.53$, $p > 0.05$, $\eta p^2 = 0.07$; Sex: $t(31) = 1.73$, $p > 0.05$, $\eta p^2 = 0.09$).

Insert Figure 5 about here

A 2x2 within-participants ANOVA of mean RTs from accurate trials (Fig. 5) revealed a significant main effect of Task, $F(1,31) = 6.3$, $p < 0.05$, $\eta p^2 = 0.17$, and a significant main effect of Block type, $F(1,31) = 35.2$, $p < 0.001$, $\eta p^2 = 0.53$. The interaction of these variables was significant, $F(1,31) = 31.9$, $p < 0.001$, $\eta p^2 = 0.51$. Follow up T-tests revealed that in the Weight task, the Garner effect ($M = 100$ ms) was significant, $t(31) = 6.7$, $p < 0.001$, $\eta p^2 = 0.59$. In contrast, there was not a significant Garner effect in the Sex task ($M = -7$ ms), $t(31) = 0.83$, $p > 0.05$, $\eta p^2 = 0.02$. Finally, an analysis comparing Control blocks across the two tasks revealed that performance on the Weight task ($M = 526$ ms) was significantly faster than the Sex task ($M = 554$ ms), $t(31) = 2.8$, $p < 0.01$, $\eta p^2 = 0.20$. Note that given the direction of this baseline difference in response times, it does not support an account of the asymmetry in Garner effects being due to the distinction between sexes in the stimuli being more salient that weight.

The counterbalanced, within-participants design of Experiment 3 offers two checks on the possible dependence of our observed asymmetry on order effects. First, we separately examined response time data from participants who performed the Weight task or the Sex task first. In both cases, the interaction of Task and Block type was significant: Weight first: $F(1,15) = 10.7$, $p < 0.01$, $\eta p^2 = 0.42$; Sex first: $F(1,15) = 25.0$, $p < 0.001$, $\eta p^2 = 0.62$. In both cases, the Garner effect was significant in the Weight task (Weight first: $M = 80$ ms; $t(15) = 3.3$, $p < 0.005$, $\eta p^2 = 0.43$; Sex first: $M = 119$ ms; $t(15) = 7.0$, $p < 0.001$, $\eta p^2 = 0.76$). Conversely, in neither case was the Garner effect significant in the Sex task (Weight first: $M = -23$ ms; $t(15) = 1.5$, $p > 0.05$, $\eta p^2 = 0.13$; Sex first: $M = 8$ ms; $t(15) = 1.1$, $p > 0.05$, $\eta p^2 = 0.07$).

Second, we separately examined the response time data from participants who performed the Control block of each task before its Orthogonal block, or vice versa. For the Weight task, the Garner effect was significant for participants who performed the Control blocks first, M=131 ms, t(15) = 6.7, $p < 0.001$, $\eta p^2 = 0.75$, and also for participants who performed the Orthogonal blocks first, M = 69 ms, t(15) = 3.4, $p < 0.005$, $\eta p^2 = 0.43$. For the Sex task, a significant Garner effect was not revealed in either task order: Control first, M = -7 ms, t(15) = 0.50, $p > 0.05$, $\eta p^2 = 0.02$; Orthogonal first: -8 ms, t(15) = 0.68, $p > 0.05$, $\eta p^2 = 0.03$.

Discussion

The results of Experiment 3 confirm the same asymmetrical pattern of Garner interference that we observed in the first two experiments is found in a within-participants design, in which each individual performed both tasks and in which the order of control and orthogonal blocks was counterbalanced. Note that our claim is not that order effects are not present. Indeed, for example, the Garner effect in the weight task is larger when the control blocks were performed first compared to when they were performed second, F(1,30) = 4.8, $p < 0.05$, $\eta p^2 = 0.14$. However, whether the data are assessed across the whole group, or split by task order, or split by block order, we do not find significant Garner effects for the sex task, and we do find them for the weight task.

Asymmetries in Garner interference have previously been revealed in studies of face perception: for example, in comparisons of identity and expression tasks (Schweinberger & Soukup, 1998; Schweinberger et al., 1999), in comparisons of sex and expression tasks (Atkinson et al, 2005), and between race, age, and emotional expression (Karnadewi & Lipp, 2011). Furthermore, this asymmetric pattern can be modulated by other variables such as familiarity (Ganel & Goshen-Gottstein, 2004) or inversion (Karnadewi & Lipp, 2011).

Asymmetric patterns of Garner interference can potentially be understood in several ways. In some cases they may arise trivially due to unbalanced perceptual discriminability of the two dimensions being tested. A highly salient distinction may be more difficult to filter than a less salient one, independent of the true separability of those dimensions. We exclude that account of the present data based on the well-matched baseline performance on our two tasks across Experiments 1 and 2. (In Experiment 3, the observed difference in baseline RT performance directly contradicts this account, in that the sex judgment was the slower of the two tasks on average).

A less trivial interpretation is that one dimension - the one that causes interference even when it is irrelevant - is acting as a “reference” for the other dimension. For example, it may be that face identity provides a reference for emotional expression, because different individuals generate expressions in idiosyncratic ways (Ganel & Goshen-Gottstein, 2004). In other words, the asymmetry reveals something about the underlying structure of the stimulus space -- the statistics of how aspects of facial appearance are correlated or not in the “real world” -- and how the brain makes use of this structure.

When considering possible mechanisms underlying such an asymmetric relationship, reference is often made to the notion of parallel-contingent processes (Turvey, 1973). Here the proposal is that while analysis of two dimensions proceeds in parallel, the developing outputs of the computations supporting one dimension (e.g. identity) are passed to and influence processing of the other dimension (e.g. expression) but not vice versa. An obvious appeal of this model over a serial model - in which one dimension is fully processed before analysis of the other begins - is that it can explain asymmetries that arise even where overall task difficulty and mean response times are roughly balanced (as here).

These previous findings and concepts are helpful to interpret the present data. First, we look to differences in the nature of the two body dimensions that we tested - the statistics of body properties found in the world. The sex category is binary, comprising males or females. Naturally there is variation in the appearance of individuals around the two poles of male and female, and likewise this can be obscured or exaggerated e.g. with clothing or in morphed stimuli. In contrast, weight naturally varies over populations in a continuous fashion (although not necessarily along a single dimension – height, muscle, and fat will all contribute to variations in body shape in potentially independent ways). Recall, however, that there is some evidence that weight-related variation in body shape is perceived categorically, at least in judgments of physical attractiveness (Tovée, Edmonds, & Vuong, 2012). Put crudely, then, the sex category can be thought of as binary “in the world” as well as “in the mind”, whereas weight is only binary “in the mind”.

Furthermore, adults of the two sexes will gain or lose weight in distinct ways, whether this is due to changes in muscle mass or adiposity, with different consequences for body shape. Thus variation in body shape due to weight is inherently dependent on the underlying sex, whereas the reverse is not true. (Note, however, that that this is further complicated by the observation that in extremely underweight or obese individuals, visual cues to sex may in fact be obscured relative to body weights nearer to the norm).

The present results show how these structural and statistical properties of body appearance are internalised by the human perceptual system involved in representing body shape. When assessing the weight of an individual, their sex cannot be readily ignored, even when it is totally task-irrelevant. In a parallel-contingent system, we suggest, information processing about sex influences the ongoing processing of other aspects related to body shape, including weight.

To provide converging evidence for this proposal, we devised a final experiment in which sex and weight judgements were tested with another task. The parallel-contingent view outlined here predicts that providing accurate advance information, in the form of a prime, about the sex of an upcoming body will facilitate a weight judgement about that body. In contrast, advance priming of the figure's weight should have no effect on a subsequent sex judgment.

Experiment 4

Introduction

Priming experiments involve the use of a cue stimulus presented before a target, where the relationship between these is manipulated (Posner, 1978; Meyer & Schvaneveldt, 1971). Congruent cues may pre-activate some relevant aspect of the target's representation, enhancing performance, whereas incongruent cues, by pre-activating an irrelevant representation, may interfere with perception of the target.

To align to the logic of the Garner paradigm, in the present study the cue stimulus was always related to the task-irrelevant stimulus dimension. That is, for a participant doing the sex task (i.e.asked to make a sex judgment about body shapes), the cue would relate to the weight of that body. Conversely, for the weight task, the cue would relate to the sex of the body. Cueing was provided by a single category-related word (e.g. "man"), to avoid cross-contamination from the cue dimension to the task dimension (which would otherwise be unavoidable if images were used as cues). In order to encourage active reliance on the cue information, cues were valid (accurately describing the upcoming body image) on 80% of trials and invalid on the remaining 20%.

We predicted that when participants carried out the Sex task, a weight-related cue word would not produce congruency effects. However, during the Weight task, we predicted that a sex-related cue would cause a congruency effect. These differing hypotheses are due to the asymmetry in information flow from ongoing parallel analyses of body weight and sex.

Methods

Participants

A new sample of 24 students at Bangor University participated, comprising 18 females, with a mean age of 22.04 (range: 19-29).

Design and procedure

This study used the images from Experiment 2 (including both image sizes). A between-participants design was employed such that half of the participants carried out the Sex task, and the remainder performed the Weight task. Participants completed 160 experimental trials over five blocks (with interleaved self-paced breaks). In 80% of trials, the cue was congruent (e.g. a cue "man" before an image of a male, in the weight task) and in the remaining 20% of trials the cue was incongruent.

In each trial, a fixation point was presented for 1 sec, followed by a cue word for 1000 ms, followed by the body stimulus (Fig. 6). These stimuli were all presented at the center of the monitor. The cues were "man" or "woman" in the weight task and "heavy" or "slim" in the sex task. The body image remained onscreen for 2 sec or until the participant responded, whichever came first. The response was made with the "f" and "j" keyboard keys; participants were reminded of the response mapping with the corresponding category names printed at the bottom left and right of the display.

The experimental trials were preceded by 48 practice trials in which the cue word on each trial was replaced with "XXXXXX".

Insert Figure 6 about here

Results

Mean accuracy across all tasks and conditions was 94% correct. It was not necessary to exclude any participants from analysis due to poor overall performance. Accuracy data were submitted to a 2x2 mixed-effects ANOVA with Task (between participants; Weight or Sex), and cue Validity (within participants; congruent or incongruent) as factors. Neither main effect nor the interaction were significant, all $F(1, 22) < 2.9$, all $p > .10$. Accordingly, and in line with the preceding experiments, our analyses focused on response time data for accurate trials.

Response time data were submitted to a 2x2 mixed-effects ANOVA with Task and cue Validity as factors (Fig. 7). The two main effects (Task: $F(1, 22) = 8.2$, $p < 0.01$, $\eta p^2 = 0.27$; Validity: $F(1, 22) = 14.1$, $p<0.005$, $\eta p^2 = 0.39$) were qualified by a significant interaction, $F(1,22) = 10.7$, $p<0.005$, $\eta p^2 = 0.33$. To break down this interaction, the Validity effect was assessed for each task separately. For the Weight task, cue validity had a significant effect, in that an invalid written cue about the sex of the target produced slower response times ($M = 905$ ms) relative to a valid sex cue ($M = 660$ ms), $t(11) = 3.6$, $p<0.005$, $\eta p^2 = 0.53$. In contrast, for the Sex task, the difference between an invalid weight cue ($M = 647$ ms) and a valid weight cue ($M = 630$ ms) was not reliable, $t(11) = 1.4$, $p>0.05$, $\eta p^2 = 0.15$. There was not a significant RT difference between the validly-cued trials of the two tasks, $t(22) = 0.71$, $p > 0.05$, $\eta p^2 = 0.02$, indicating that the baseline difficulty of the two tasks was roughly comparable.

Insert Figure 7 about here

Discussion

Participants carrying out the weight task were affected by the congruency of the sex cue with the body that they judged, whereas the congruency of weight primes in the sex task did not have a significant effect on RTs. This pattern was as predicted, and is consistent with the findings of Experiments 1-3, and with the proposed organization of body weight and sex representations.

In the absence of a "neutral" prime condition, we do not make claims about whether the validity effect in the weight task was a result of facilitation from valid cues or inhibition from invalid cues. However the latter interpretation is hinted at by the extremely slow mean response times to the invalid trials in the Weight task, suggesting that activating the incorrect sex of an upcoming body strongly engages the associated weight representations, which then must be suppressed in order to make the correct response. Further experiments could clarify this detail, but it is not critical to our central claim.

General Discussion

We know that the body and its movements convey socially-relevant information to observers (Mehrabian, 1972; Argyle, 1975; Rosenthal, Hall, DiMatteo, Rogers, & Archer, 1979; Knoblich, Thornton, Grosjean, & Shiffrar, 2006; Peelen & Downing, 2007; de Gelder, Van den Stock, Meeren, Sinke, Kret, & Tamietto, 2010; Downing & Peelen, 2011; Johnson & Shiffrar, 2012; Yovel and O'Toole, 2016). The aim of this study was to learn about how our mental representations of bodies encode and capture these social cues. In particular, we have focused on body shape, to reveal how the visual cues to sex and weight are processed.

Our main approach to this problem was to use the Garner interference task, which has been used in other domains to reveal the major boundaries of internal representations of visual stimuli - and more specifically to ask to what extent different dimensions of a stimulus may be coded in parallel or in an interdependent fashion. The Garner task is typically interpreted to capture processing at a perceptual level (i.e. analysis and categorization of the stimulus) rather than at a response level (i.e. assigning a stimulus category to a specific motor output). We favour that interpretation here: because in Experiments 1, 2, and 4 the irrelevant stimulus dimension is never associated to any response, interference from that dimension cannot be at the response level.

Our main finding is the asymmetry in interference between sex and weight, which defies a simple explanation in terms of either fully parallel or fully-integrated processing. We interpret the asymmetry to mean that the organisation of the perceptual systems that analyse bodies parallels some of the real-world structure in the way that sex and weight interact to influence visible body shape. This is congruent with similar interpretations of previously reported asymmetric interference in face perception.

A broad distinction that has been proposed to hold for the visual representation of bodies (and faces; Duchaine and Yovel, 2015) is one between static and dynamic cues (Giese & Poggio, 2003; Vangeneugden, Peelen, Tadin, & Battelli, 2014). This is based partly on neural evidence for distinct brain regions that respond preferentially to either the static form of bodies / body parts, or to the dynamics of body movements even in the absence of surface cues, as found in point-light displays. For example, fMRI studies reveal two ventral occipitotemporal regions - the extrastriate body area (EBA; Downing, Jiang, Shuman, & Kanwisher; 2001) and the fusiform body area (FBA; Peelen & Downing, 2005; Schwarzlose, Baker, & Kanwisher, 2005) - that respond selectively to images of bodies and body parts, even in schematic forms such as stick figures and silhouettes. These regions also respond to human biological motion displays, although this has been attributed to extraction of body structure from motion rather than to dynamics per se (e.g. Downing, Peelen, Wiggett, & Tew, 2006). In contrast, regions of the posterior superior temporal sulcus responds strongly to dynamic displays of human movement but only weakly to static body images (Grossman & Blake, 2002; Beauchamp, Lee, Haxby & Martin, 2002).

The present study can be seen as extending our understanding of how neural representations within the ventral, “static” pathway are organised. Note, however, that the socially-relevant cues that are signalled about others by the body can generally be conveyed by both kinds of signals, cutting across this ventral/dorsal distinction. For example, movement patterns are rich in information about sex, sexuality, and gender (Kozlowski & Cutting, 1977; Barclay, Cutting & Kozlowski, 1978; Johnson & Tassinary, 2005; Johnson, Gill, Reichman, & Tassinary, 2007). Indeed, recent neuroimaging studies have begun to highlight how encoding of faces, bodies, and actions that abstracts across cue sources (e.g. static/dynamic; verbal/visual) spans the lateral and ventral occipitotemporal cortex (e.g. Hafri et al., 2017; O'Toole et al., 2014; Wurm & Lingnau, 2015; for review see Lingnau & Downing, 2015).

In light of findings such as these, an obvious future direction is to use the present approach to test other categorical dimensions that are conveyed by the body and to test these in both static and dynamic stimuli. A finding of common patterns of Garner interference/independence for dimensions such as sex, weight, age, and health, across tests relying on body shape or patterns of body movement, would suggest a mental organisation of body representations that cuts across these different signal sources.

With the present study, there is now evidence from the Garner approach spanning faces, voices (Mullennix & Pisoni, 1990; Green, Tomiak, & Kuhl, 1997), and bodies, all of which contribute in various ways to person perception. By comparing and contrasting results of these studies, it may eventually be possible to identify general principles that describe how different dimensions will interact. For example, Atkinson et al. (2005) argued that the invariance of face dimensions drives asymmetries in interference: invariant dimensions (e.g. sex, identity) will tend to provide a better basis for computing more dynamic, variant dimensions (e.g. expression) than vice versa, and so they will be harder to selectively ignore. This view broadly fits the present data, in that weight changes over time (albeit normally slowly) whereas sex typically remains fixed (aside from the case of gender reassignment).

Finally, considering the multiple person cues available in faces, bodies, and voices together raises the possibility of extending the Garner task across these different cues. For example, how does task-irrelevant variation of the sex of the body interfere with analysis of facial expressions, or vice versa? This approach might prove useful as researchers increasingly seek to understand social perceptual cues with a "whole person" approach that spans specific cue sources (Ghuman, McDaniel, & Martin, 2010; Quadflieg, Flannigan, Waiter, Rossion, Wig, Turk, & Macrae, 2011; Lai, Oruc, & Barton, 2012; Bernstein, Oron, Sadeh, & Yovel, 2014; Brandman & Yovel, 2014; Kaiser, Strnad, Seidl, Kastner, & Peelen, 2014; Fisher & Freiwald, 2015; Harry, Umla-Runge, Lawrence, Graham, & Downing, 2016).

Concluding remarks

In sum, our results have led to a testable proposal about the encoding of body shape related to socially-relevant traits. Studies using a similar approach may help develop a richer model of body perception, in part by shedding light on the relative contribution of stimulus properties (e.g. static vs dynamic) and ecologically-meaningful dimensions (e.g. sex, age, health) to body encoding. This would be useful for more recent efforts that draw together multiple cues (faces, bodies, voices) for a general model of person perception (Minnebusch & Daum, 2009; Yovel & Belin, 2013; Yovel & O'Toole, 2016) as well as for computational approaches that speak to the interactions among social-cognitive and social-perceptual processes (Freeman & Ambady, 2011).

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Table 1. Mean accuracy by condition for all experiments.

Experiment 1

Stimulus	Task	Condition	Mean	SE
Body	Weight	Control	88.3%	1.4%
Body	Weight	Orthogonal	87.5%	1.7%
Body	Sex	Control	90.0%	1.3%
Body	Sex	Orthogonal	90.3%	1.6%
Geometric Shape	Weight	Control	91.9%	1.1%
Geometric Shape	Weight	Orthogonal	89.4%	1.6%
Geometric Shape	Sex	Control	93.0%	1.0%
Geometric Shape	Sex	Orthogonal	94.3%	1.3%

Experiment 2

Task	Condition	Mean	SE
Weight	Control	94.5%	0.8%
Weight	Orthogonal	94.9%	0.7%
Sex	Control	94.4%	0.8%
Sex	Orthogonal	94.1%	1.0%

Experiment 3

Task	Condition	Mean	SE
Weight	Control	93.1%	0.5%
Weight	Orthogonal	93.9%	0.4%
Sex	Control	88.4%	0.4%
Sex	Orthogonal	87.5%	0.6%

Experiment 4

Task	Condition	Mean	SE
Weight	Valid	93.7%	1.1%
Weight	Invalid	93.3%	1.1%
Sex	Valid	94.8%	1.2%
Sex	Invalid	92.6%	1.7%

Figure Captions

Figure 1. Examples of both a slim and a large female body stimulus, and slim and large hourglass stimuli, from Experiment 1.

Figure 2. Mean response time results of Experiment 1 in milliseconds. Error bars are +/- 1 standard error of the mean. Garner interference was asymmetrical for body stimuli. Orthogonal variations on sex interfered with the Weight task, whereas the converse was not observed. In contrast, with simple geometric control shapes, equivalent Garner interference was found for Geometric Shape and Size tasks designed to be comparable to the sex and weight judgments that were performed on body stimuli.

Figure 3. Examples of stimuli from Experiment 2. Clockwise from top left: slim females, slim males, heavy males, heavy females.

Figure 4. Mean response time results of Experiment 2 in milliseconds. Error bars are +/- 1 standard error of the mean. Garner interference was asymmetric between tasks requiring judgments of the sex or weight of bodies depicted in photographs.

Figure 5. Mean response time results of Experiment 3 in milliseconds. Error bars are +/- 1 standard error of the mean. Garner interference was asymmetric between tasks requiring judgments of the sex or weight of bodies depicted in photographs.

Figure 6. Schematic of trial structure from Experiment 4. The top panel shows a validly-cued trial from the Weight task. The bottom panel shows an invalidly-cued trial from the Sex task. Images not to scale.

Figure 7. Mean response time results of Experiment 4 in milliseconds. Error bars are +/- 1 standard error of the mean. The validity of pre-cues about the task-irrelevant dimension of a body stimulus influenced response times in the Size task (where sex was pre-cued) but not the Sex task (where weight was pre-cued).