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View-dependent accuracy in body mass judgements of female bodies

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ABSTRACT

A fundamental issue in testing body image perception is how to present the test stimuli. Previous studies have almost exclusively used images of bodies viewed in front-view, but this potentially obscures key visual cues used to judge adiposity reducing the ability to make accurate judgements. A potential solution is to use a three-quarter view, which combines visual cues to body fat that can be observed in front and profile. To test this hypothesis, 20 female observers completed a 2-alternative forced choice paradigm to determine the smallest difference in body fat detectable in female bodies in front, three-quarter, and profile view. There was a significant advantage for three-quarter and profile relative to front-view. Discrimination accuracy is predicted by the saliency of stomach depth, suggesting that this is a key visual cue used to judge body mass. In future, bodies should ideally be presented in three-quarter to accurately assess body size discrimination.

1. Introduction

There has been a steady rise in obesity levels in the developed world with a concomitant pressure on public health resources (Ogden, Carroll, Kit, & Flegal, 2014; Swinburn et al., 2011). In tandem with this rise, there has also been an increase in the levels of negative body image, which may have contributed to the increasing prevalence of eating disorders and conditions such as muscle dysmorphia (Cash & Pruzinsky, 2002; Grabe, Ward, & Hyde, 2008; Pope, Phillips, & Olivardia, 2000; Swami et al., 2010). From both an epidemiological and clinical point of view, it is therefore important to develop psychometrically sound measurement scales for the self-assessment of body size/shape (Gardner & Brown, 2010; Thompson & Gray, 1995). Many different such measures have been constructed, but amongst the most commonly used include: (a) figural body scales that are composed of a series of images of either men or women varying in adiposity from emaciated to obese (Stunkard, Sorensen, & Schulsinger, 1983), (b) computerized tasks which either present many examples of such images in random order, one at a time, or which allow the stimulus to be smoothly animated between minimum and maximum body size endpoints (Gardner & Brown, 2010). Depending on the task, participants either estimate their own body size by choosing images closest to the size/shape they believe themselves to have or would like to have. Alternatively, participants make decisions about whether any particular stimulus is smaller/larger than the body size they believe themselves to have or would like to have (the difference between the two is a measure of body dissatisfaction) (Brodie, Bagley, & Slade, 1994; Gardner & Brown, 2011). In this paper we assert that judgements of this kind should properly be thought of as magnitude estimation tasks and should therefore follow Weber's law (1834). We then ask whether any of the three commonly used orientations for whole body stimuli (side, front, and three-quarter view) produce participant responses that conform to this expectation. Failure to do so may lead to systematic patterns of over- and/or under-estimation when people judge their body size.

1.1. Weber's law

In whatever perceptual domain, be it sensory or proprioceptive, human magnitude estimation has been shown to follow Weber's law almost without exception. This is the phenomenon whereby the smallest difference between a pair of stimuli that can be reliably told apart (the just noticeable difference or JND) is a constant proportion of the stimulus magnitude. To illustrate, as a reference weight gets bigger, then a test weight which is to be compared to it needs to be heavier, by a constant proportion of the reference, in order that the test is correctly identified as being heavier than the reference (i.e., the Weber fraction $K = \Delta I/I$, where I = reference stimulus magnitude and K = constant). Weber's law only holds for physical properties that have magnitude. This is the mathematical property which determines whether an object is larger or smaller

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than other objects of the same kind, and is represented numerically by values that start at zero and must thereafter be positive. While rare exceptions do exist, for example for pure tone and noise intensity discrimination at high intensities in the auditory domain (Jesteadt, Wier, & Green, 1977), Weber's law should nevertheless be considered ubiquitous for human magnitude perception.

In the case of body mass index (BMI), we should expect that a plot of the JND for BMI (y-axis) as a function of reference BMI (x-axis) should be a straight line with a positive slope, and the Weber fraction, *K*, should be constant across the reference BMI range. In principle therefore, a useful way to design a figural scale for body size estimation would be based on JNDs for BMI. Starting from the smallest body size that one might want participants to judge, the next largest figure on the scale might be 2 JNDs larger, the next 2 JNDs larger still, and so on to the end point for the scale. Indeed, the Dol Pain scale was designed exactly in this way (Adair, Stevens, & Marks, 1968) and is still in use today.

A useful way to think about JNDs is in terms of the precision of magnitude judgements. Precision is said to be high when the JND is small. Precision is related to the statistical concept of variability (standard deviation, quartile deviation, or range), and to the concept of reliability or random error ("noise"). Since according to Weber's law, JND increases linearly with reference stimulus magnitude, this means that the precision with which judgements can be made falls correspondingly – hence leading to the need for bigger differences between stimulus pairs with increasing reference magnitude. However, a second implication is that the ideal stimuli for a figural scale should also give rise to the smallest possible JNDs at each reference magnitude. Given the example above of a straight-line plot of JND for BMI as a function of reference BMI, then the ideal figural scale would not only have a constant Weber fraction, *K*, but also an intercept for the relationship which is as close to zero as possible. This would lead to more precise body size estimates, lower variability across participants, and improved psychometric properties of the task. In the case of identifying individuals at risk from obesity in epidemiological samples, reducing the JNDs for the figural scales (e.g., as reported by Dratva et al., 2016) would lead to improved sensitivity and specificity.

1.2. Test validity

An important attribute of any psychometric test is that of content validity: "... if the items of a test can be shown to reflect all aspects of the subject being tested, then it is per se valid, given that the instructions are clear. This is not simply face validity, which is related to the appearance of the test items ..." (Kline, 2015). With figural body scales and their computerized equivalents, an important consideration regarding content validity is the orientation of the body in the scale. The reason this is important is because, even though perceptual estimates of BMI should follow Weber's law, because BMI has magnitude, if the stimuli representing changes in BMI lack content validity, then we may nevertheless fail to observe Weber's law behaviour. Bodies in published figural scales have almost exclusively been presented in front-view (Gardner, Jappe, & Gardner, 2009; Harris, Bradlyn, Coffman, Gunel, & Cottrell, 2008; Li, Hu, Ma, Wu, & Ma, 2005; Peterson, Ellenberg, & Crossan, 2003; Swami, Salem, Furnham, & Tovée, 2008). However, to our knowledge, there have been no systematic studies to confirm whether the front view is indeed optimal – and here we would define optimal as producing participant responses which follow Weber's law. Indeed, there are reasons for believing that the front view may obscure visual cues normally used by an observer to judge body mass, thereby reducing content validity. For example, stomach depth, which has been suggested to be an important cue to body mass judgements (Cornelissen, Hancock, Kiviniemi, George, & Tovée, 2009; Rilling, Kaufman, Smith, Patel, & Worthman, 2009; Smith, Cornelissen, & Tovée, 2007; Tovée, Maisey, Emery, & Cornelissen, 1999) may be harder to judge in front-view than in profile. The use of front-view may also make it difficult to accurately estimate body fat in populations of African descent where the pattern of fat deposition differs from European populations with more fat deposited on the thighs and buttocks which are not visible in front-view (Cohen, Bernard et al., 2015; Cohen, Ndao et al., 2015; Marlowe, Apicella, & Reed, 2005).

1.3. The current study

Here we sought to determine which of three stimulus orientations: frontal, three-quarter or side view, is most suitable for use in body size estimation tasks. So, it is an investigation of basic stimulus properties. To do this, we used a 2-alternative forced choice (2-AFC) paradigm to determine the smallest difference in body fat that could be detected at the three different orientations (i.e., the JND for BMI). Our criteria for suitability were: (a) that participant responses obeyed Weber's law empirically because that is what we should expect them to do theoretically, (b) that participant responses maximize precision by minimizing JNDs across the reference range. We emphasize that the current study is an investigation of participants' basic ability to discriminate differences in body size between pairs of images. This is a judgement about others, made from a third-person point of view, which does not require participants to refer to their own body image in any way. Therefore, we should not expect these psychophysical estimates to be influenced by participants' body satisfaction or their attitudes to body shape, weight or eating, or indeed their own BMI.

2. Methods

2.1. Participants

We used a repeated measures design with two within-participants factors: CGI model orientation (3 levels: three-quarter, front, and side views) and reference BMI (4 levels: 15, 20, 27, & 36). We recruited 5 female participants to pilot this experiment. None of the participants who took part in this pilot study also took part in the main study. To estimate the sample size required for the main study from the pilot data, we used GLIMMPSE (General Linear Multivariate Model Power & Sample Size; Kreidler et al., 2013). We calculated conservative multivariate tests (by scaling the calculated covariance matrix by a factor of 2) of the interaction between main effects. This showed that a sample of 12 participants would be sufficient to quantify the main effects and interactions when modelling JND as a function of stimulus BMI and stimulus orientation, at a nominated alpha level of .01 and a power of .90. To offset attrition in participant numbers and/or unexpected sources of variability, we recruited 20 female participants (age $M = 25.40$ years, $SD = 8.40$) for this study from staff and students at Northumbria University in the UK. The participants had a mean BMI of 22.7 and a *SD* of 4.0. The BMI values of the participants range from 15.40 to 31.20 (3 are underweight, 11 are in the normal range, 5 are overweight and 1 is obese). We asked all potential participants whether they had a current diagnosis or history of an eating disorder and excluded those individuals from this study.

2.2. Stimuli

We wanted to identify the smallest change in BMI that observers could detect (the JND), at four separate points along the BMI continuum, corresponding to the World Health Organization's classification for underweight, normal, overweight, and obese. Accordingly, we chose reference BMIs for each of these four groups: 15, 20, 27, & 36 respectively. To create stimulus images which