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Original Article

# Categorical perception of human female physical attractiveness and health

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**Abstract**

Using realistic three-dimensional female body models, we found evidence for a categorical perception of female physical attractiveness and health in male and female Caucasian observers. In a rating task, we showed that these bodies were rated for attractiveness or health in the same way as real bodies. In a two-alternative forced-choice task, we showed that these bodies were categorized into attractive vs. unattractive or healthy vs. unhealthy nonlinearly, which allowed us to estimate the position of a categorical boundary between attractive and unattractive or healthy and unhealthy bodies. In a delayed match-to-sample task, we measured the sensitivity of discrimination between pairs of bodies. We found significantly better discrimination for pairs that crossed the attractive/unattractive or healthy/unhealthy boundary than pairs that did not, even though the physical changes in both conditions were identical. Thus, categorical perception enhances the perception of physical changes that cross the boundary between discrete perceptual categories of important judgments such as attractiveness or health, which can be a cue for mate selection.


*Keywords:* Categorical perception; Attractiveness; Female bodies

## 1. Introduction

One of the most fundamental problems facing individuals is mate selection. Thus, it is important that they have a means to efficiently evaluate the attractiveness of potential partners because the wrong choice will have a negative impact on their reproductive success (Buss, 2006; Zebrowitz & Rhodes, 2002). As attractiveness can be a cue to fitness and reproductive potential, we might expect very strong selective pressures for the development of perceptual mechanisms that effectively evaluate attractiveness. It is generally assumed that body attractiveness judgments are graded along a continuum from attractive to unattractive through a series of intermediate levels (e.g., Fan, Liu, Wu, & Dai, 2004; Swami, Caprario, Tovée, & Furnham, 2006, Swami, Neto, Tovée, & Furnham, 2007; Thornhill & Grammer, 1999; Tovée, Reinhardt, Emery, & Cornelissen, 1998, Tovée, Hancock, Mahmoodi, Singleton, & Cornelissen, 2002). However, it is perceptually demanding to make fine-grain judgments of physical attractiveness. To simplify such judgments so that appropriate responses can be acted upon, a potentially more effective approach would be to initially assign bodies into discrete perceptual categories, such as attractive or unattractive. This kind of categorical perception is well documented for many aspects of perception. For example, facial identity (e.g., Beale & Keil, 1995; Levine & Beale, 2000; Rotshtein, Henson, Treves, Driver, & Dolan, 2005), gender (e.g., Webster, Kaping, Mizokami, & Duhamel, 2004), facial expressions (e.g., Calder, Young, Perrett, Etcoff, & Rowland, 1996; Etcoff & Magee, 1992) and race (e.g., Cosmides, Tooby, & Kurzban, 2003; Levine & Angelone, 2002) all show categorical perception. However, little research has examined categorical perception for evolutionary fitness cues, such as attractiveness.

In the current study, we examined the extent to which observers perceive female physical attractiveness and health categorically and how this categorical perception, if present, affects observers' ability to discriminate body shapes. A key feature of categorical perception is that although an observer will be very sensitive to changes occurring across a boundary between two perceptual categories (such as between attractive and unattractive bodies), observers will be much less sensitive to the *same amount* of physical changes in stimuli if they occur within a perceptual category (such as discriminating among bodies that are all attractive). A well-

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known example of categorical perception is the recognition of human facial expressions. We are very good at distinguishing the changes in facial feature configurations that push a facial expression across a categorical boundary, such as between happy and sad, but we are much less sensitive to the same amount of changes in facial configuration within a category, such as happy (e.g., Calder et al., 1996; de Gelder, Teunisse, & Benson, 1997; Etcoff & Magee, 1992; Young et al., 1997).

Categorical perception would allow a more accurate classification of bodies into attractive vs. unattractive or healthy vs. unhealthy categories but necessarily reduces finer-grain judgments within a perceptual category. However, in reproductive terms, the important strategy is to avoid unattractive partners, who are potentially unhealthy and nonfertile. Discrimination within categories is still possible but less important. If partner choice is from an “attractive pool”, all of the potential outcomes should be a reasonably good choice. Indeed, given an individual’s limited neural processing resources, it would make sense to sacrifice within-category shape sensitivity to improve across-category shape sensitivity. Thus, categorical perception could enhance the accuracy of health judgments.

To investigate how observers perceive female physical attractiveness and health, we systematically manipulated realistic female body models to alter their level of fatness from underweight to obese. Previous studies have suggested that altering apparent body fat will alter the attractiveness and perceived health level of the female bodies (e.g., Smith, Cornelissen, & Tovée, 2007; Tovée Reinhardt, Emery, & Cornelissen, 1998, Tovée, Furnham, & Swami, 2007). Following Calder et al.’s (1996) paradigm, male and female observers were asked to perform various perceptual tasks: a rating task, a two-alternative forced-choice task and a delayed match-to-sample (DMS) task. The rating task allowed us to compare the pattern of attractiveness or health ratings with previous studies to confirm that the body models were rated in the same way as real bodies. The forced-choice task forced observers to either categorize bodies as attractive vs. unattractive or healthy vs. unhealthy, which allowed us to estimate the position of the putative categorical boundary. The DMS task allowed us to test whether there was an improved perceptual performance in discriminating between female bodies across this categorical boundary, which has been shown to exist in categorical studies using faces (e.g., Calder et al., 1996).

## 2. Experiment 1: judgments of female attractiveness

### 2.1. Methods

#### 2.1.1. Participants

We recruited 40 male and 40 female observers (mean age 23.1 years, S.D. 3.2 years) who all completed the DMS task. We then randomly assigned them into two groups. The first group of 20 male and 20 female observers carried out the rating task. Due to a technical error, the data for one male and one female was lost. The second group of 20 males and 20 females carried out the forced-choice task.

#### 2.1.2. Apparatus and materials

Figs. 1A and 1B show the three-dimensional (3D) body models used as stimuli. The use of realistic body models allows much greater control over the differences in physical characteristics between bodies. Features such as skin colour and texture and overall proportions (such as the relative length of the torso to the legs) do not change, which they would if we used images of real bodies. The models were created using Poser 6 (Smith Micro Graphics, http://graphics.smithmicro.com/go/poser). The two female models used as templates were Victoria 4.0 and Emma, both produced by Daz3D (http://www.daz3d.com). Victoria appeared to be a conventional nonmuscular body, whereas Emma had a more toned and muscular body. The use of two body sets allowed us to test whether the preferences generalised across body types. The bodies were dressed in the conforming two-piece swimming costume from the Victoria 4.0 Basic Wear clothing package. Body shape was altered using the Victoria 4.0 shape morphs. For both bodies, we produced two prototypes, altering the body sizes along the fatness morph available in Poser to produce underweight and obese bodies.

To produce a continuum of body sizes between the two prototypes, for each body model, we morphed the 3D geometry of its prototypes in 3D Studio Max (Autodesk, http://usa.autodesk.com). The original underweight body was designated as body size 0 (0%), and the original obese body was designated as body size 10 (100%). Nine bodies were generated at 10% steps along the morphed continuum between them, making a total of 11 bodies in each continuum. An obvious concern is that these bodies will not change shape and size in an anthropometrically valid way. However, the shape and volume of the models can be measured and compared against corresponding anthropometric measures from real bodies. Such an analysis suggested that morphing between prototype body models resulted in shape and size changes that are very similar to the shape and size changes seen in real bodies for different body mass indices (Appendix A).

All body models were rendered from a full frontal (0°) viewpoint as 24-bit colour JPEGs and were 480 pixels in width by 680 pixels in height (Figs. 1A and 1B). We also rendered all models from four additional viewpoints by rotating the virtual camera −10°, −30°, +10° and +30°, about the full frontal viewpoint. The same lighting and camera settings were used for all renderings.

All three tasks were run in Matlab version 7.1 (Mathworks Inc., www.mathworks.com) using the Psychtoolbox extension (Brainard, 1997; Pelli, 1997). The observers viewed the images on a flat-panel, 19-in. monitor. Half the participants completed the tasks with the Victoria body set and the other half with the Emma set.

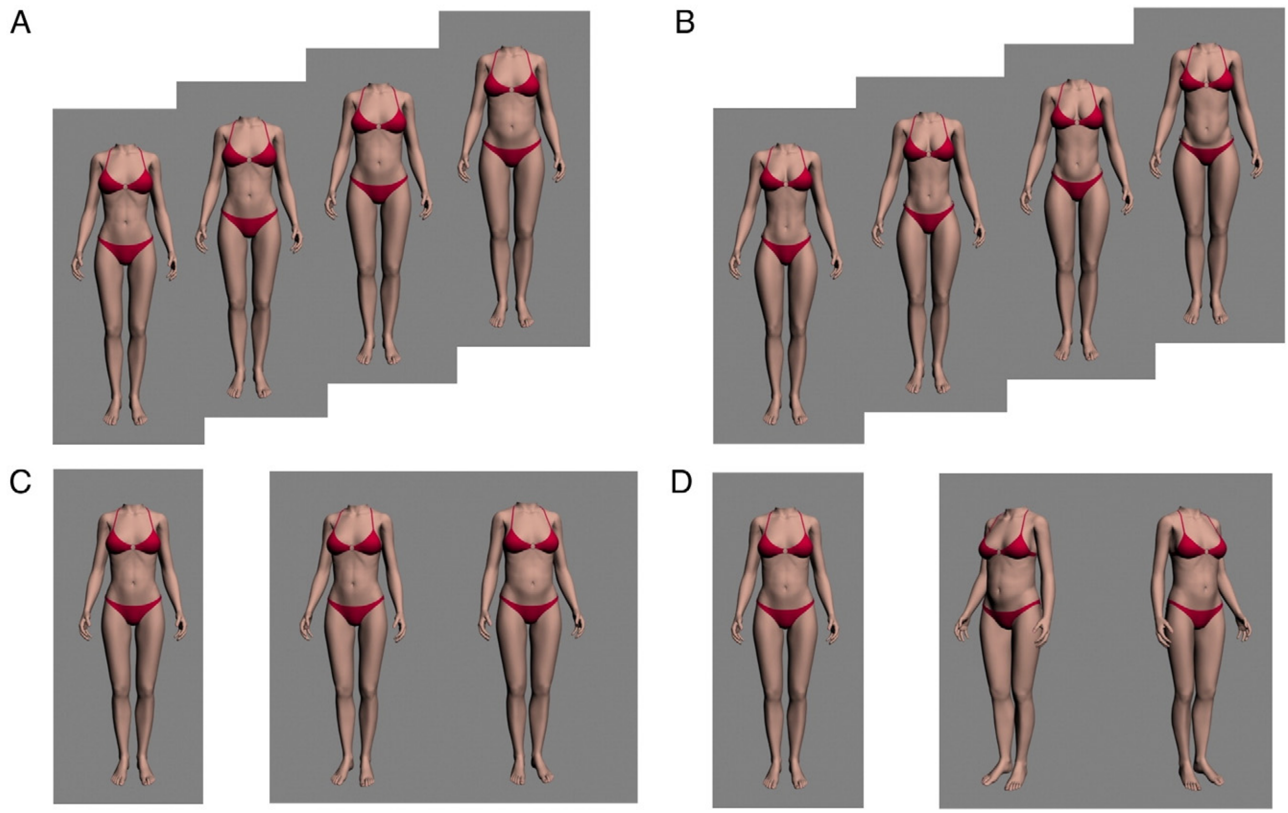


Fig. 1. Rendered examples of the realistic 3D female body models used in this experiment. (A) Examples from the Victoria 4.0 body set. (B) Examples from the Emma body set. (C and D) Examples of the stimuli used in the DMS task.

### 2.1.3. Procedure

*2.1.3.1. Attractiveness rating task.* Each rating trial began with a 250-ms presentation of a central fixation cross followed by a blank interval of 250 ms, and then a body from one of the continua was displayed from the frontal (0°) viewpoint. Subjects were asked to rate the body's attractiveness from 1 (*very unattractive*) to 7 (*very attractive*). The image stayed on the screen until the observer responded. The images were presented in a random order, and each image was presented four times, making a total of 44 presentations. Observers were allowed as much time as needed to rate the body.

*2.1.3.2. Two-alternative forced-choice task.* Each forced-choice trial began with a 250-ms presentation of a central fixation cross followed by a blank interval of 250 ms, and then a body from one of the continua was displayed, again from the frontal viewpoint. The observer categorized the body as either attractive or unattractive by pressing one of two buttons. The assignment of buttons to an attractiveness category was counterbalanced. The image stayed on screen until the observer responded. Each image was presented 10 times, making a total of 110 presentations. All trials were presented in a random order.

*2.1.3.3. DMS task.* On each trial, the observer was presented with a single body from the frontal viewpoint for 750 ms followed by a blank screen for 500 ms, and then two images were presented side by side for 1 s. The pair of images differed from each other by two steps along the body size continuum (Fig. 1). To make the task more difficult and prevent observers from using image cues, the pair of bodies was presented either from a 20° viewpoint difference (−10°, +10°) or from a 60° viewpoint difference (−30°, +30°), as shown in Figs. 1C and 1D, respectively. Thus, the matching test body was always rotated either 10° or 30° in either direction from the sample body. One image of the pair was always identical in its body fat level to the first image presented (differing only by a rotation in depth). Observers were instructed to discriminate between the two bodies and choose the body in the pair (left or right) that matched the sample as quickly and as accurately as possible by pressing the appropriate key. The matching body occurred equally often on the left or on the right in the test display. All 9 two-step pairings of the body morph continuum were presented in the four possible configurations (i.e., A-AB, A-BA, B-AB and B-BA) and in both orientation conditions (20° and 60° viewpoint difference). The 72 trials were presented in random order on two separate blocks, with a short break between each block, for a total of 144 trials.

## 2.2. Results

Recall that all observers were tested with the DMS task prior to either the rating task or the forced-choice task. For this and the subsequent experiment, we first report results for the rating task to determine whether body models would be rated in a similar pattern to photographs of real bodies. We then used the forced-choice task to determine the putative category boundary for attractive and unattractive bodies (e.g., Calder et al., 1996). Finally, for the DMS task, we tested whether observers were faster and/or more accurate to discriminate body pairs when they crossed the putative boundary (across-category discrimination) than when they did not (within-category discrimination). In all analyses, we averaged across the two template bodies (Victoria and Emma). Separate analyses are reported in the appendix. For all analyses, we used $\alpha$=0.05 as our significance level.

### 2.2.1. Attractiveness rating task

Fig. 2A shows the average attractiveness rating plotted against the body size continuum. Moving along the continuum from underweight to obese, the results show that attractiveness rating increased to a peak around bodies 2 and 4, and then fell to a low level by bodies 6 and 7. Interestingly, there was an asymmetry in the ratings, with the underweight models (bodies 0 and 1) being rated as more attractive than the obese models (bodies 9 and 10). We performed a two-way analysis of variance (ANOVA) on the mean rating, with gender as a between-participant factor and body size as a within-participant factor. There were significant changes in the mean rating with changes in body size ($F_{10,360}$=166.0, $p$<.001). The gender of the observer was also a significant factor in the ratings ($F_{1,36}$=13.3, $p$<.001). The female observers rated all bodies as being more attractive than the male observers, although both male and female observers ranked the bodies for attractiveness in a very similar way (Spearman rank correlation, $r$=0.98, $p$<.001). There was no significant interaction between gender and body size.

### 2.2.2. Two-alternative forced-choice task

Fig. 2B shows the average proportion of attractive responses plotted against the body size continuum. Like the rating task, the results show that the proportion of attractive responses increased to a peak around bodies 2 through 4, and then fell sharply to a low level by body 6. An ANOVA conducted on the proportion attractive responses show that body size was a significant factor ($F_{10,380}$=98.6, $p$<.001) but that gender was not. There was a significant interaction between gender and body size ($F_{10,380}$=5.2, $p$<.001), but we do not make any theoretical interpretation of this interaction. As with the rating data, both male and female observers categorized the bodies in a very similar way (Spearman rank correlation, $r$=0.92, $p$<.001).

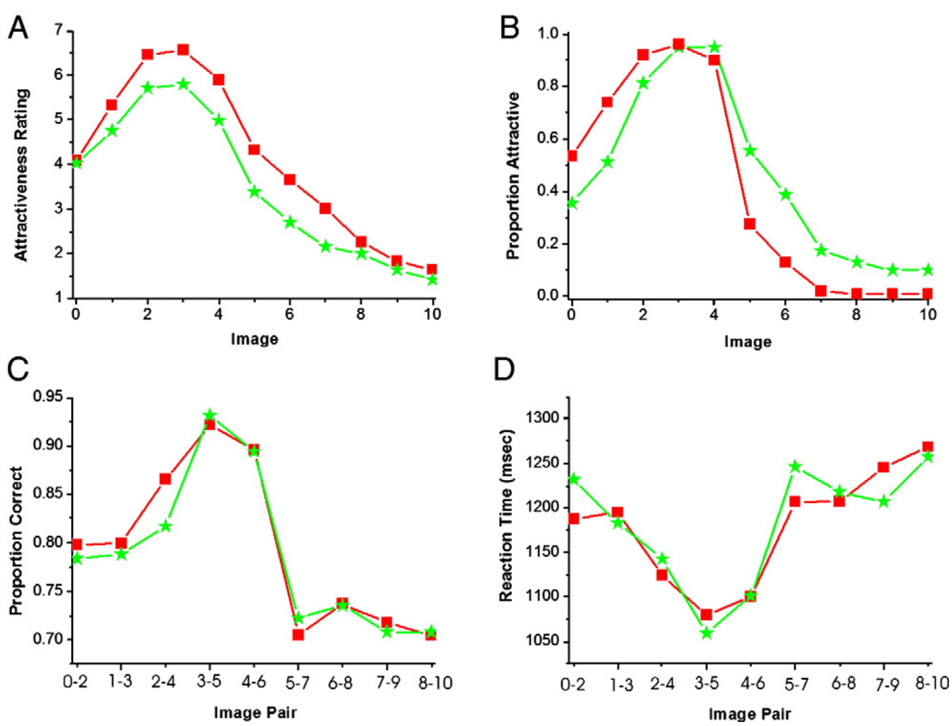


Fig. 2. (A) Mean attractiveness ratings for the female (red squares and lines) and the male (green stars and lines) observers as a function of body size. (B) Mean proportion attractive responses for the female (red squares and lines) and the male (green stars and lines) observers as a function of body size. (C) Mean proportion correct for the DMS task for the female (red squares and lines) and the male (green stars and lines) observers as a function of body pair. Each pair represents two steps (20%) between two body sizes. (D) Mean correct reaction times for the DMS task for the female (red squares and lines) and the male (green stars and lines) observers as a function of body pair.

#### 2.2.3. DMS task

The accuracy with which the male and female observers were able to discriminate between the different body pairs was very similar (Spearman correlation, $r$=0.87, $p$=.002). Figs. 2C and 2D, respectively, show a plot of the accuracy and response time as a function of body pair.

We were interested in whether performance on the DMS task would differ for discriminating between bodies that crossed a categorical boundary and those that did not, even though the physical changes in both conditions were equated. We therefore used the forced-choice data to define any category boundaries for both groups of observers. We decided that the cutoff point for a body to be attractive was being categorized as such on 50% or more of the trials, averaging responses across the male and female observers. Based on this criterion, body pairs 0–2, 3–5 and 4–6 were classified as across-category pairs, and the other six pairs were classified as within-category pairs (Fig. 2B). We note that there is possible gender difference at body size 0: The female observers are slightly above the 50% cutoff, whereas the male observers fall below this cutoff. However, a $t$ test conducted at this body size for the male observers shows that the mean proportion attractive responses ($M$=53.5%) was not significantly above chance ($t_{19}$=0.99). Thus, to err on the side of caution, we consider pair 0–2 as an across-category pair in our analysis, as this seems to be the most conservative judgment to make. Note that similar results were obtained when we analysed the DMS data using only pairs 3–5 and 4–6 as our across-category pairs.

After defining our across-category and within-category pairs, we performed separate three-way ANOVAs on the mean accuracy and mean correct response time (RT) with gender as a between-participant factor and pair type (across-category, within-category) and orientation (20° viewpoint difference, 60° viewpoint difference) as within-participant factors. In this and the subsequent experiment, we also eliminated trials in which RTs were less than 350 ms or longer than 4800 ms to account for anticipatory responses and outliers. This criterion eliminated less than 1.0% of the correct RT data.

For accuracy, the results show a main effect of pair type ($F_{1,76}$=168.2, $p$<.001). Observers were more accurate with the across-category pairs (87.1%, S.E. 0.6%) than with the within-category pairs (75.1%, S.E. 0.7%). There was also a significant effect of orientation ($F_{1,76}$=8.8, $p$<.004), with observers being slightly more accurate on smaller rather than larger viewpoint differences (20° difference: 82.1%, S.E. 0.8%; 60° difference: 80.0%, S.E. 0.8%). There was no significant effect of gender or significant interactions between any of the factors. For the RT data, the ANOVA showed a significant main effect of pair type ($F_{1,76}$=49.0, $p$<.001). Observers responded more quickly with the across-category pairs (1121 ms, S.E. 17 ms) than with the within-category pairs (1202 ms, S.E. 19 ms). Orientation was also significant ($F_{1,76}$=25.1, $p$<.001), with observers responding more quickly for smaller than larger viewpoint differences (20° difference: 1138 ms, S.E. 18 ms; 60° difference: 1185 ms, S.E. 18 ms). Again, gender was not significant, and there were no significant interactions between any of the factors.

## 3. Experiment 2: judgments of female health

### 3.1. Methods

To determine whether the same pattern of results extended to judgments of health, we ran the same three tasks with a new set of observers making health judgments. We recruited 20 male and 20 female observers (mean age 24.2 years, S.D. 3.7 years) who first completed the DMS task. We then randomly assigned them into two groups. The first group of 10 male and 10 female observers carried out the rating task, then the forced-choice task. The second group of 10 males and 10 females carried out the forced-choice task, then the rating task. Thus, all observers were tested in all three tasks. Other than these differences, experiment 2 was identical to experiment 1 and used the same 3D model bodies.

### 3.2. Results

#### 3.2.1. Heath rating task

As in experiment 1, we first report results for the rating and forced-choice tasks, and then the results for the DMS task. Fig. 3A shows the average health rating plotted against the body size continuum. Moving along the continuum from underweight to obese, the results showed that health rating increased to a peak around bodies 2 through 4, and then fell to a low level by bodies 6 and 7. Like the attractiveness ratings, there was an asymmetry in the ratings, with the underweight models (bodies 0 and 1) being rated as healthier than the obese models (bodies 9 and 10). An ANOVA showed that there were significant changes in the mean rating with changes in body size ($F_{10,380}$=69.8, $p$<.001). The gender of the observer was not a significant factor in the ratings; indeed, both the male and female observers ranked the body sizes for attractiveness in a very similar way (Spearman rank correlation, $r$=0.99, $p$<.001). There was no significant interaction between gender and body size. Importantly, the ratings of attractiveness and health are highly correlated (Spearman rank correlation, $r$=0.99, $p$<.0001; compare Figs. 2A and 3A).

#### 3.2.2. Two-alternative forced-choice task

Fig. 3B shows the average proportion healthy responses plotted against the body size continuum. The results show that the proportion healthy responses increased to a peak around bodies 2 through 4, and then fell to a low level by body 6. However, health responses did not fall as sharply as attractiveness responses (compare Figs. 2B and 3B). A two-way ANOVA showed that body size was a significant factor ($F_{10,380}$=45.9, $p$<.001). The gender of the observer was not a significant factor in the ratings, nor did gender and body size interacted. Again, both male and female

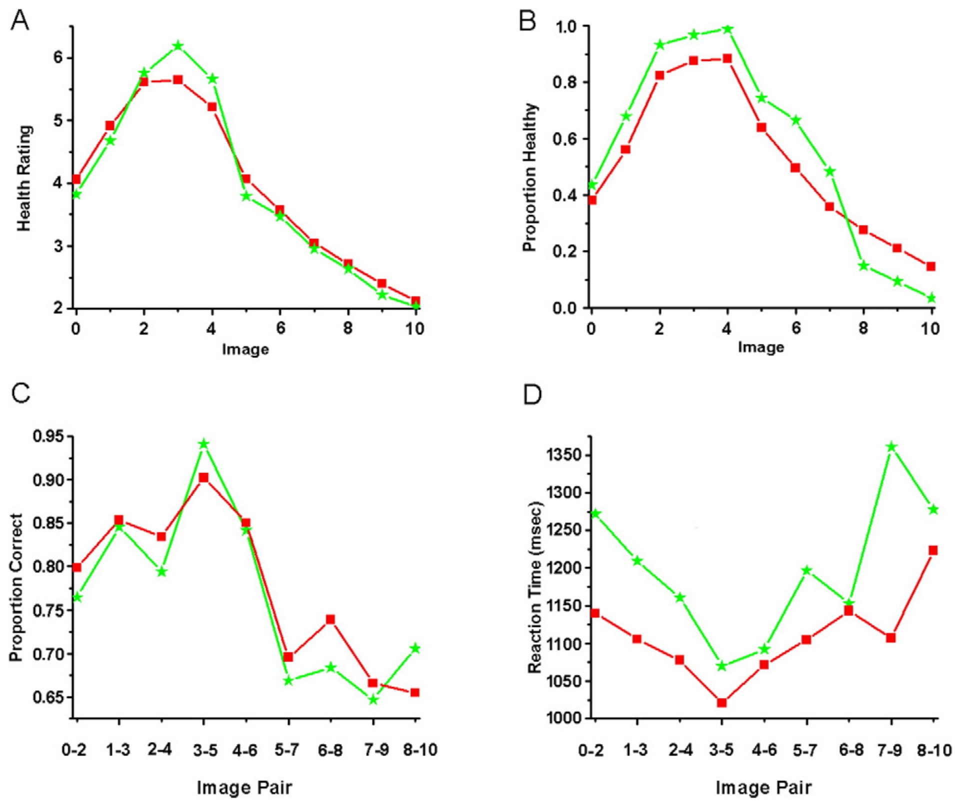


Fig. 3. (A) Mean health ratings for the female (red squares and lines) and the male (green stars and lines) observers as a function of body size. (B) Mean proportion healthy responses for the female (red squares and lines) and the male (green stars and lines) observers as a function of body size. (C) Mean proportion correct for the DMS task for the female (red squares and lines) and the male (green stars and lines) observers as a function of body pair. (D) Mean correct reaction times for the DMS task for the female (red squares and lines) and the male (green stars and lines) observers as a function of body pair.

observers categorize the bodies in a very similar way (Spearman rank correlation, $r$=0.97, $p$<.001). As with the rating task, the results for attractiveness and health are highly correlated (Spearman rank correlation, $r$=0.92, $p$<.0001; compare Figs. 2B and 3B).

*3.2.3. DMS task*

The accuracy with which male and female observers were able to discriminate between bodies was very similar (Spearman correlation, $r$=0.93, $p$<.001). Figs. 3C and 3D show a plot of the accuracy and RT, respectively, as a function of body pair for the male and female observers.

Following experiment 1, we used the 50% cutoff point from the forced-choice data for a body to be considered healthy or unhealthy. This criterion resulted in the same across-category pairs (0–2, 3–5, 4–6) and within-category pairs. The health function for both the rating and forced-choice task is slightly broader than the equivalent attractiveness functions, and the 4–6 pair falls less clearly across the categorical border, particularly for the male observers. However, we consider this pair as an across-category pair to err on the side of caution and for comparability to experiment 1.

We performed separate three-way ANOVAs on the mean accuracy and mean correct RT with gender as a between-participant factor and pair type and orientation as within-participant factors. For accuracy, the results show a main effect of pair type ($F_{1,38}$=98.2, $p$<.001). Observers were more accurate with the across-category pairs (85.0%, S.E. 1.0%) than with the within-category pairs (73.4%, S.E. 0.9%). There was no significant effect of gender and orientation, and there were no significant interactions between any of the factors. For the RT data, the ANOVA showed a significant main effect of pair type ($F_{1,38}$=25.2, $p$<.001), with observers responding more quickly for across-category pairs (1100 ms, S.E. 27 ms) than for within-category pairs (1167 ms, S.E. 29 ms). Orientation was also significant ($F_{1,38}$=36.2, $p$<.001), with observers responding more quickly for smaller than larger viewpoint differences (20° difference: 1163 ms, S.E. 41 ms; 60° difference: 1094 ms, S.E. 36 ms). Again, gender was not significant, and there were no significant interactions between any of the factors.

## 4. Discussion

Our results provide strong support for the hypothesis that body attractiveness is perceived categorically and that attractiveness is closely linked to the perception of health. Both the male and female observers were more accurate and quicker to discriminate between female bodies that crossed an attractive/unattractive or healthy/unhealthy boundary than they were to discriminate between bodies within a category. Importantly, the amount of physical changes to the stimuli was equated in both the cross-category and within-category conditions by our morph manipulation. This cross-categorical enhancement of discrimination is diagnostic of categorical perception and mirrors the finding from previous studies looking at the categorical perception of facial expressions (e.g., Calder et al., 1996; de Gelder et al., 1997; Etcoff & Magee, 1992; Young et al., 1997). Although our conclusions only apply to female bodies, we speculate that the categorical perception of male bodies is also likely to occur. However, the features that predict male attractiveness or health may differ from those that predict these judgements in women (e.g., Fan, Dai, Liu, & Wu, 2005; Maisey, Vale, Cornelissen, & Tovée, 1999; Sell et al., 2009).

Modifying the apparent fatness of the bodies appears to duplicate the pattern of ratings found when real bodies are judged for attractiveness and health (e.g., Fan et al., 2004; Scott, Bentley, Tovée, Ahamed, & Magid, 2007; Swami & Tovée, 2007; Tovée et al., 2002, 2007). Those bodies that appeared to have a high body fat level were rated as unattractive and unhealthy, while those with a moderately low body fat level are rated as more attractive and healthy. This pattern was mirrored by the response in the forced-choice task, in which the higher fat bodies were designated as unattractive and unhealthy and those bodies with a lower body fat were designated as attractive and healthy.

It has been suggested that attractiveness is based on the perceived health and reproductive potential of the body being assessed (e.g., Buss, 2006; Thornhill & Gangestad, 1999). Our results are consistent with this suggestion. First, like attractiveness, we found a heightened sensitivity to physical changes if bodies crossed the healthy/unhealthy boundary. Second, the ratings and forced-choice tasks show a similar pattern of responses for both attractiveness and health judgments, as predicted by some studies for female bodies (e.g., Scott et al., 2007; Tovée et al., 2007).

Our results further suggest that male and female observers rank female bodies for attractiveness in a very similar way. This finding is consistent with mate selection theory (e.g., Buss, 1987), which postulates not only that an individual will be able to judge the attractiveness of members of the opposite sex, but also that he or she will know his or her attractiveness relative to other members of the same sex. This finding is also consistent with previous rating studies that have shown a close correlation in the ranking of female attractiveness and health by male and female observers (e.g., Cornelissen, Hancock, Kiviniemi, George, & Tovée, 2009; Smith et al., 2007; Tovée et al., 2007).

The pattern of perceptual behaviour in the forced-choice and DMS tasks suggests that the observers are making categorical judgments when judging attractiveness and health. It is unlikely that these judgments are based on specific low-level features or elements of the image (such as colour or texture; Beale & Keil, 1995) because these features are held constant in our stimuli. However, it is possible that observers looked at individual body parts, rather than the whole body. For example, a recent eye-movement study has suggested that, when judging attractiveness, observers primarily fixate on the stomach and central torso (Cornelissen et al., 2009), and it may be that a particular feature, such as the stomach, might be used to categorize attractiveness in our study. However, functional imaging and behavioural studies have shown that, like faces, bodies are judged as a single pattern rather than in a piecemeal manner (e.g., Lawson, Clifford, & Calder, 2009; Peelen & Downing, 2007; Reed, Stone, Bozova, & Tanaka, 2003; Taylor, Wiggett, & Downing, 2007), suggesting that the bodies are categorized as a whole pattern rather than on the basis of a single part.

Categorical perception was first proposed for speech perception (Harnad, 1987a; Liberman, Harris, Hoffman, & Griffith, 1957; Lisker & Abramson, 1964). It remains a controversial concept, and its precise definition is the subject of much disagreement (e.g., McMurray, Aslin, & Toscano, 2009; Pastore, 1987; Schouten, Gerrits, & van Hessen, 2003). In the present study, we are not arguing for a strong form of categorical perception in which there is little or no differentiation between individuals within a category. Rather, we suggest that, although the two categories are perceived as qualitatively different, it is still possible to make differentiations between individuals within a category. This is a form of categorization similar to that found in studies of race perception (Cosmides et al., 2003; Levine & Angelone, 2002).

Given that we have only a limited amount of processing power in our brains to perform the perceptual tasks required of us, the form of categorical perception our results support seems to be an efficient way to allocate limited neural resources. Instead of being equally sensitive to the physical changes in a body across the whole continuum of possible shapes, we concentrate our sensitivity at the most important part of the continuum: the point at which a body changes from being attractive to unattractive or healthy to unhealthy. The corollary of this heightened sensitivity at a perceptual boundary between categories is that the sensitivity at other parts of the continuum is necessarily reduced. However, as the most important outcome of any mate selection is to choose a fit and healthy partner and avoid an unhealthy option (Buss, 2006; Zebrowitz & Rhodes, 2002), this arrangement may represent the best way of allocating our finite sensory processing resources.

Perceptual categories may be innate or based on learned preferences (Harnad, 1987b). It is likely the case that judgments of female body attractiveness and health are learned. Previous studies have suggested the existence of differences in attractiveness preferences between different observer groups, such as between different socioeconomic and cultural groups (e.g., Scott et al., 2007; Swami et al., 2007; Swami & Tovée, 2005, 2007). For example, although UK observers prefer a female body mass at the lower end of the normal range, observers in rural South Africa prefer a much heavier body mass (Tovée, Swami, Furnham, & Mangalparsad, 2006, Tovée et al., 2007). In the UK, a high body mass is correlated with low health and low fertility, while the converse is true in rural South Africa. Our results would suggest that the position of the categorical boundary is likely to be different in these groups to reflect these different preferences. So although the same physical dimensions (such as body size or shape) seem to be important in determining female attractiveness, the point along those dimensions at which a body becomes attractive or unattractive/healthy or unhealthy may be determined by a learned response specific to an observer's environment.

It is important to note that we found that the underweight models (bodies 0 and 1) are judged to be less attractive and less healthy than the slightly heavier models (bodies 2 and 3) but not as unattractive or unhealthy as our most obese models (bodies 7 through 10). The reduction in attractiveness and health at the underweight end is consistent with previous studies using photographs of real bodies that report that low-body-fat photographs are rated as less attractive and healthy than normal-weight bodies (e.g., Scott et al., 2007; Smith et al., 2007; Swami & Tovée, 2005; Tovée, Maisey, Emery, Cornelissen, 1999; Tovée et al., 2002, 2007). However, there was no clear categorical boundary for our most underweight bodies. It seems most likely that the absence of a clear boundary in the underweight range is because we did not synthesize extremely-low-fat models in our study. Indeed, very-low-fat real bodies are rated as extremely unattractive and unhealthy (e.g., Scott et al., 2007; Tovée et al., 1999, 2006, 2007; Appendix A).

In sum, categories shape how we perceive and interact with the world around us. The perceptual system uses categorical perception to make rapid decisions about important social signals such as facial expression (e.g., Calder et al., 1996). In mate selection, the utility of being able to process the visual information about a body's physical characteristics and categorize the body as attractive or unattractive, healthy or unhealthy, fertile or unfertile and so on allows the appropriate behavioural orientation and response to be rapidly made.

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### Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.evolhumbehav.2011.05.008.

## References

Beale, J. M., & Keil, F. C. (1995). Categorical effects in the perception of faces. *Cognition*, *57*, 217–239.

Brainard, D. H. (1997). The psychophysics toolbox. *Spatial Vision*, *10*, 433–436.

Buss, D. M. (1987). Sex differences in human mate selection criteria: an evolutionary perspective. In C. Crawford, & M. Smith, & D. Krebs (Eds.), *Sociobiology and psychology: ideas, issues and application* (pp. 335–351). Hillsdale, NJ: Erlbaum.

Buss, D. M. (2006). Strategies of human mating. *Psychological Topics*, *15*, 239–260.

Calder, A. J., Young, A. W., Perrett, D. I., Etcoff, N. L., & Rowland, D. (1996). Categorical perception of morphed facial expressions. *Visual Cognition*, *3*, 81–117.

Cornelissen, P. L., Hancock, P. J. B., Kiviniemi, V. W., George, H. R., & Tovée, M. J. (2009). Patterns of eye-movements when male and female observers judge female attractiveness, body fat and waist-to-hip ratio. *Evolution & Human Behavior*, *30*, 417–428.

Cosmides, L., Tooby, J., & Kurzban, R. (2003). Perceptions of race. *Trends in Cognitive Sciences*, *7*, 173–179.

de Gelder, B., Teunisse, J. P., & Benson, P. J. (1997). Categorical perception of facial expressions: categories and their internal structure. *Cognition and Emotion*, *11*, 1–23.

Etcoff, N. L., & Magee, J. J. (1992). Categorical perception of facial expressions. *Cognition*, *44*, 227–240.

Fan, J., Dai, W., Liu, F., & Wu, J. (2005). Visual perception of male body attractiveness. *Proceedings of the Royal Society of London Series B*, *272*, 219–226.

Fan, J., Liu, F., Wu, J., & Dai, W. (2004). Visual perception of female physical attractiveness. *Proceedings of the Royal Society of London Series B*, *271*, 347–352.

Harnad, S. (1987a). Psychophysical and cognitive aspects of categorical perception: a critical overview. In S. Harnad, Ed. *Categorical perception: the groundwork of cognition* (pp. 1-25). Cambridge: Cambridge University Press.

Harnad, S. (1987b). Category induction and representation. In S. Harnad, (Ed.), *Categorical perception: the groundwork of cognition* (pp. 535–565). Cambridge: Cambridge University Press.

Lawson, R. P., Clifford, C. W. G., & Calder, A. J. (2009). About turn: the visual representation of human body orientation revealed by adaptation. *Psychological Science*, *20*, 363–371.

Levine, D. T., & Beale, J. M. (2000). Categorical perception occurs in newly learned faces, other-race faces, and inverted faces. *Perception and Psychophysics*, *62*, 386–401.

Levine, D. T., & Angelone, B. L. (2002). Categorical perception of race. *Perception*, *31*, 567–578.

Liberman, A. M., Harris, K. S., Hoffman, H., & Griffith, B. (1957). The discrimination of speech sounds within and across phoneme boundaries. *Journal of Experimental Psychology*, *54*, 358–368.

Lisker, L., & Abramson, A. (1964). A cross-language study of voicing in initial stops: acoustical measurements. *Word*, *20*, 384–422.

Maisey, D. S., Vale, E. L., Cornelissen, P. L., & Tovée, M. J. (1999). Characteristics of male attractiveness for women. *Lancet*, *353*, 1500.

McMurray, B., Aslin, R. N., & Toscano, J. C. (2009). Statistical learning of phonetic categories: insights from a computational approach. *Developmental Science*, *12*, 369–378.

Pastore, R. E. (1987). Categorical perception: some psychophysical models. In S. Harnad, (Ed.), *Categorical perception: the groundwork of cognition* (pp. 29–85). Cambridge: Cambridge University Press.

Peelen, M. V., & Downing, P. E. (2007). The neural basis of visual body perception. *Nature Reviews Neuroscience*, *8*, 636–648.

Pelli, D. G. (1997). The VideoToolbox software for visual psychophysics: transforming numbers into movies. *Spatial Vision*, *10*, 437–442.

Reed, C. L., Stone, V. E., Bozova, S., & Tanaka, J. (2003). The body-inversion effect. *Psychological Science*, *14*, 302–308.

Rotshtein, P., Henson, R. N., Treves, A., Driver, J., & Dolan, R. J. (2005). Morphing Marilyn into Maggie dissociates physical and identity face representations in the brain. *Nature Neuroscience*, *8*, 107–113.

Schouten, B., Gerrits, E., & van Hessen, A. (2003). The end of categorical perception as we know it. *Speech Communication*, *41*, 71–80.

Scott, I., Bentley, G. R., Tovée, M. J., Ahamed, F. U., & Magid, K. (2007). An evolutionary perspective on male preferences for female body shape. In A. Furnham, & V. Swami (Eds.), *The body beautiful: evolutionary and socio-cultural perspectives* (pp. 108–128). Basingstoke Hampshire; Palgrave Macmillan.

Sell, A., Cosmides, L., Tooby, J., Sznycer, D., von Rueden, C., & Gurven, M. (2009). Human adaptations for the visual assessment of strength and fighting ability from the body and face. *Proceedings of the Royal Society of London Series B*, *276*, 575–584.

Smith, K. L., Cornelissen, P. L., & Tovée, M. J. (2007). Color 3D bodies and judgments of human female attractiveness. *Evolution & Human Behavior*, *28*, 48–54.

Swami, V., Caprario, C., Tovée, M. J., & Furnham, A. (2006). Female physical attractiveness in Britain and Japan: a cross-cultural study. *European Journal of Personality*, *20*, 69–81.

Swami, V., Neto, F., Tovée, M. J., & Furnham, A. (2007). Preferences for female body weight and shape in three European countries. *European Psychologist*, *12*, 220–228.

Swami, V., & Tovée, M. J. (2005). Female physical attractiveness in Britain and Malaysia: a cross-cultural study. *Body Image*, *2*, 115–128.

Swami, V., & Tovée, M. J. (2007). Perceptions of female body weight and shape among indigenous and urban Europeans. *Scandinavian Journal of Psychology*, *48*, 43–50.

Taylor, J., Wiggett, A., & Downing, P. (2007). Functional MRI analysis of body and body part representations in the extrastriate and fusiform body areas. *Journal of Neurophysiology*, *98*, 1626–1633.

Thornhill, R., & Gangestad, S. W. (1999). Facial attractiveness. *Trends in Cognitive Sciences*, *3*, 452–460.

Thornhill, R., & Grammer, K. (1999). The body and face of woman: one ornament that signals quality? *Evolution and Human Behavior*, *20*, 105–120.

Tovée, M. J., Furnham, A., & Swami, V. (2007). Healthy body equals beautiful body? Changing perceptions of health and attractiveness with shifting socioeconomic status. In A. Furnham, & V. Swami (Eds.), *The body beautiful: evolutionary and socio-cultural perspectives* (pp. 108–128). Basingstoke Hampshire; Palgrave Macmillan.

Tovée, M. J., Hancock, P. J. B., Mahmoodi, S., Singleton, B. R. R., & Cornelissen, P. L. (2002). Human female attractiveness: waveform analysis of body shape. *Proceedings of the Royal Society of London Series B*, *269*, 2205–2213.

Tovée, M. J., Maisey, D. S., Emery, J. L., & Cornelissen, P. L. (1999). Visual cues to female physical attractiveness. *Proceedings of the Royal Society of London Series B*, *266*, 211–218.

Tovée, M. J., Reinhardt, S., Emery, J. L., & Cornelissen, P. L. (1998). Optimum body-mass index and maximum sexual attractiveness. *Lancet*, *352*, 548.

Tovée, M. J., Swami, V., Furnham, A., & Mangalparsad, R. (2006). Changing perceptions of attractiveness as observers are exposed to a different culture. *Evolution and Human Behavior*, *27*, 443–456.

Webster, M. A., Kaping, D., Mizokami, Y., & Duhamel, P. (2004). Adaptation to natural facial categories. *Nature*, *428*, 557–561.

Young, A. W., Rowland, D., Calder, A. J., Etcoff, N. L., Seth, A., & Perrett, D. (1997). Facial expressions megamix: tests of dimensional and category accounts of emotion recognition. *Cognition*, *63*, 271–313.

Zebrowitz, L. A., & Rhodes, G. (2002). Nature let a hundred flowers bloom: the multiple ways and wherefores of attractiveness. In G. Rhodes, & L. A. Zebrowitz (Eds.), *Facial attractiveness: evolutionary, cognitive, and social perspectives* (pp. 262–293). New York; Ablex.