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GRADIENT SHIFTS WITH NATURALLY OCCURRING HUMAN FACE STIMULI

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The present research examined stimulus generalization and gradient shifts on a dimension involving human faces. Twenty undergraduates were instructed to examine the proportion of the total face length that lay between the tip of the nose and the end of the chin. The face stimuli were images of actual people shown on a computer screen; no face was shown more than once. All of the participants received discrimination training. The positive stimuli were faces with average proportions (ratios of 0.356 to 0.365). The negative stimuli were faces with very small proportions (ratios less than or equal to 0.315) for half of the participants, and faces with very large proportions (ratios greater than or equal to 0.405), for the other half. The generalization test consisted of images from 5 categories of proportions, ranging from very small to very large. The results of both conditions included a shift in the gradient away from the negative stimuli.

Stimulus generalization is defined as "the transfer of a learned response from one stimulus to another, similar stimulus" (Mazur, 2002, p. 363). The usual pattern is for responses to be distributed in either an exponential or Gaussian manner around a stimulus correlated with reinforcement (Cheng, 2002; Ghirlanda & Enquist, 2003). The typical generalization gradient can be altered, however, if participants are trained both to respond to a positive stimulus (the S+) and to refrain from responding to a negative stimulus (the S-). Instead of a symmetrical gradient, a disproportionate number of responses are made to stimuli on the opposite end of the stimulus dimension from the S-. This altered pattern of responding is termed an *area shift* when the area under the gradient has shifted away from the S-, and a *peak shift* when the modal response, or "peak" of the gradient, has shifted (Honig & Urcuioli, 1981; Rilling, 1977).

Research on gradient shifts traditionally has made use of stimuli that vary along a single dimension, such as hue (e.g., Hanson, 1959), line

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length (Pokrzywinski, 1970), tone frequency (e.g., Galizio, 1985), and time (Spetch & Cheng, 1998). In recent years, however, researchers also have begun to use stimuli that vary along multiple dimensions. For example, in one line of research, participants are trained and tested with human face stimuli (Lewis & Johnston, 1999; McLaren & Mackintosh, 2002; Spetch, Cheng, & Clifford, 2004). Images of two faces provide the end points of the dimension, and morphing varying proportions of the two faces together creates the intermediate steps. Although the morphing procedure creates images that vary in a number of regards, and it is not possible to determine which variations in the stimuli control responding, discrimination training on this dimension also produces gradient shifts away from the S-.

The present research further examined the generality of gradient shifts. Once again, the research used a stimulus dimension consisting of images of people's faces. However, the images were of actual people, rather than of morphed faces. Specifically, the stimulus dimension consisted of the ratio of two distances on the human face: the length of the lower face (i.e., the distance between the tip of the nose to the end of the chin) to the total length of the face. One subset of ratios was designated the S+, and a second subset was designated the S-. A broad range of ratios was used for the generalization test.

The stimulus dimension consisted of a ratio of distances for two reasons. First, the selected dimension was relatively unfamiliar to the participants and minimized the likelihood that previous experience would affect performances. Second, the dimension permitted each of the images used during training and testing to be of a different person; that is, the ratios provided a common metric for images that varied among such dimensions as the particular facial features, gender, or head size of the individual. In this sense, the research was able to more closely model a typical feature of the natural environment; instead of examining whether the gradient would shift away from a single, discrete S-, the research examined whether the gradient would shift away from an entire category of similar stimuli.

Method

Participants

The participants were 20 undergraduate students recruited from lower-level psychology courses. Participants earned extra course credit in exchange for their time.

Apparatus

Participants sat at a long table that was divided into four workstations, separated from each other by wooden dividers. Computers were located below the table, out of sight of the participants. A 17-in. Samsung DynaFlat monitor (Model 700DF) and a keyboard were placed on the surface of the table. The monitor was directly at eye level, approximately 48 cm from the participants, and the keyboard was in front of the monitor. A researcher sat at a desk 2.5 m behind the participants while data collection was in progress.

Stimuli

The stimuli consisted of images of human faces. Images were obtained from the website of universities, social organizations, and businesses based in the United States and Europe. All of the images were of people judged to be in early-to-middle adulthood. The images also included equal numbers of men and women, and one third of the images were of ethnic minorities. To minimize the possibility that the persons pictured would be familiar to the participants, none of the images were of public figures or of people residing in the upper Midwest. To ensure that the two facial dimensions could be readily discerned, images were excluded of persons that were not looking directly forward, that were open-mouthed or smiling broadly, that had facial hair or were wearing glasses, or that had hairlines that could not be clearly observed.

Once 300 suitable pictures were obtained, the images were cropped so that none included more than the head, neck, and shoulders. The images were also resized to a dimension of 325 x 325 pixels, so that some would not be larger than others. Two features of each face were then measured to the nearest 0.5 mm: the distance from the tip of the nose to the end of the chin, and the distance from the top of the face (measured from the hairline) to the end of the chin. The stimulus dimension consisted of ratios of the former distance to the latter. Not all of the 300 images were used in the course of the experiment. Those images that were used had ratios that fell into one of five categories of stimuli. The categories were enumerated 1 for very small ratios (less than or equal to 0.315), 2 for small ratios (between 0.336 and 0.345), 3 for average ratios (between 0.356 and 0.365), 4 for large ratios (between 0.376 and 0.385), and 5 for very large ratios (greater than or equal to 0.405). An illustration of the five types of ratios is shown in Figure 1.

Very Small Ratio (1) | (2) | Average Ratio (3) | (4) | Very Large Ratio (5)

Figure 1: An illustration of the five categories of ratios.

Procedure

At the beginning of the session, participants were shown several examples of small, average, and large ratios, and they were instructed to respond only whenever average ratios (the S+) were shown. Ten participants were randomly assigned to a condition in which the negative stimuli were very short ratios, and the other 10 were assigned to a condition in which the negative stimuli were very large ratios. During discrimination training, each image was visible for 7 s. A response could be made at any point during the first 5 s. During the final 2 s of the trial, a message above the image indicated whether the response (or absence of one) was "Correct" or "Incorrect." During an intertrial interval of 10 s, the message "Please Wait" appeared on the computer screen.

Training ended after 25 trials, 13 of which included the S+ and 12 the S-. The generalization test consisted of 50 trials (10 from each of the five categories of ratios). Each test image was shown for 5 s, and responses produced the message "Response Registered." As was the case with discrimination training, participants were instructed to "Please Wait" during a 10-s intertrial interval. Experimental sessions were approximately 30 to 40 min in duration.

Pilot testing revealed that some participants were unable to distinguish S+ from S-. Therefore, a criterion was adopted in which data were included in the analysis only if at least two thirds of the responses to the training stimuli were accurate. Data were replaced in 12 cases in which the criterion was not met.

Results

Figure 2 shows the generalization gradients for the two conditions.

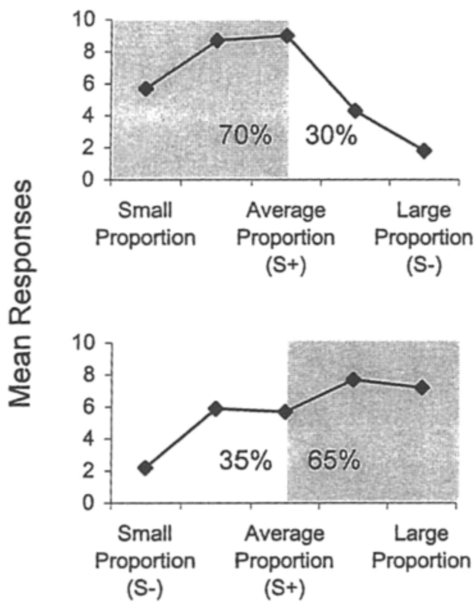

Figure 2: Generalization gradients for the very large (top panel) and very small (bottom panel) S- conditions. The percentages illustrate the proportion of responses to stimuli on either side of the S+. The side of the dimension opposite the S- has been shaded gray.

The gradient shifted away from the S- under both conditions, and a peak shift additionally was obtained when the S- consisted of very small ratios (the left panel). For purposes of the statistical analysis, the five categories were given numerical values ranging from 1 (for very small ratios) to 5 (for very large ratios); average ratios (the S+) were assigned a value of 3. The resulting mean of the generalization gradient was 3.43 for the very small S- condition (indicating a shift towards larger-than-average ratios) and 2.60 for the very large S- condition (indicating a shift towards smaller-than-average ratios). The means of the gradients were found to differ reliably between the two conditions, $t(18) = 5.52$, $p < 0.001$. To determine whether the shifts from the S+ were reliable, a one-sample *t* test was conducted in which the individual means within each condition were tested against a criterion value of 3. For both conditions, the degree of shift was statistically significant; for the very small S- condition, $t(9) = 4.28$, $p < 0.01$, and for the very large S- condition, $t(9) = -3.58$, $p < 0.01$.

Discussion

Participants received discrimination training on a stimulus dimension involving images of human faces. The positive stimuli were images in which the proportion of the lower face length to the total face length was average, and the negative stimuli were images in which the proportion was either very large or very small. A disadvantage of using a stimulus dimension based on human faces is that the total variation in the stimuli is relatively small (in this case, the difference between the smallest and largest ratios was only 0.10). Even though the negative stimuli were based on the extreme ends of the dimension, a relatively large proportion of the participants were unable to master the discrimination.

To familiarize the participants with the ratios and improve the likelihood that the relevant dimension would control behavior, the participants were shown examples of small, average, and large ratios before the experiment began. At the same time, the participants were instructed to respond only when a face with an average proportion was shown. Given that both small and large ratios were at least implicitly negative, it might be expected that gradient shifts would not be observed; that is, a shift in responding away from one set of negative stimuli would be negated by a simultaneous shift away from the opposite set of negative stimuli (cf. Hanson, 1961). Because gradient shifts were obtained, it seems that the one set of negative stimuli shown during discrimination training (i.e., the S-) had a disproportionate influence on responding.

The most noteworthy feature of the present research is that it sheds light on the generality of the gradient shift phenomenon. Ghirlanda and Enquist (1999, 2003) have suggested that gradient shifts (or at least the underlying processes) may help explain the preference for supernormal stimuli observed with some animal species. Other authors have suggested that gradient shifts may help explain why an image of a person with exaggerated or caricatured features may be more readily recognized (and even preferred) than an image of the same person with normal features (Lewis & Johnston, 1999; Ramachandran & Hirstein, 1999). However, experiments to test these propositions are lacking. By designating entire categories of stimuli positive and negative, the research allowed training and testing to occur with a wide variety of people's faces. In this sense, the present research incorporated a feature of judgments about stimuli that is characteristic of the natural environment, but which has not been present in earlier studies on gradient shifts. The finding of gradient shifts under these conditions makes more plausible the suggestion that discrimination training can alter responses to naturally occurring stimuli.

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