FIRST-ORDER AND SECOND-ORDER PATTERN PSYCHOPHYSICS

Jiro Gyoba

Department of Psychology, Graduate School of Arts and Letters, Tohoku University,
Kawauchi 27-1, Sendai, Japan
gyoba@sal.tohoku.ac.jp

Abstract

Pattern psychophysics involves intrinsically difficult problems. It is not easy to determine a relevant physical parameter for shapes and forms to be judged. Moreover, stimulus patterns always produce various psychological responses such as regularity, complexity, goodness, beauty, or preference. Therefore, in this study, we tentatively propose two kinds of pattern psychophysics. In first-order pattern psychophysics, functional relationships between variables that describe physical features of patterns and intermediate perceptual or affective dimensions such as regularity or softness are derived by multidimensional analyses. In second-order psychophysics, correspondences between the obtained intermediate dimensions and higher-order perceptual or affective properties such as goodness, beauty, or attractiveness are further examined by appropriate multivariate data analyses. Typical studies in first-order and second-order pattern psychophysics are introduced and their versatile utilities are discussed.

Pattern psychophysics refers to the field of study that relates physical variables that objectively describe the characteristics of stimulus patterns with the psychological variables obtained as responses to the patterns (Ichikawa and Gyoba, 1984).

Pattern psychophysics involves intrinsically difficult problems. We cannot easily determine a relevant physical parameter for shapes and forms to be judged. In most cases, physical variables regarding patterns have been determined based on the individual researcher's assumptions or perspectives. For example, Garner and Clement (1973) propose a variable called "ESS (equivalent set size)" for predicting the goodness of patterns. They postulated eight kinds of pattern transformations and defined ESS as the number of different patterns generated by the transformations. Smaller ESSs mean that the patterns are more invariant against the transformations and eventually become redundant. ESS should be regarded as a quasi-physical or semi-physical variable of patterns, since it depends on the postulated transformations. Such incomplete objectivity of stimulus variables is one of the crucial problems in pattern psychophysics (Ichikawa and Gyoba, 1985). Moreover, multiple variables are often necessary to describe stimulus patterns, and the selection of the variables also depends on the researchers' assumptions or empirical knowledge.

Stimulus patterns always produce various psychological responses from basic perceptual or affective levels (such as regularity or softness) to higher-order cognitive or aesthetic levels (such as goodness or attractiveness).

In order to cope with the abovementioned difficult and complicated problems, we tentatively propose two kinds of pattern psychophysics in this study (Table 1). In first-order pattern psychophysics, functional relationships between variables that describe physical features of patterns and intermediate perceptual or affective dimensions such as regularity or softness are derived by multidimensional analyses. In second-order psychophysics, correspondences between the obtained intermediate dimensions and higher-order perceptual or affective properties such as goodness, beauty, or attractiveness are further examined by appropriate multivariate data analyses. The idea of classifying the variables into three levels is based on the studies by Oyama, Miyano, and Yamada (2003) and Yamaguchi, Wang, and Shiina (2004); however, in the present study, the classification was conducted in a more comprehensive manner.

In the following two sections, we introduce the effective applications of first-order and second-order pattern psychophysics in the research of pattern goodness and facial attractiveness.

Table 1. Tentative proposal of first-order and second-order pattern psychophysics

Quasi-physical variables	Intermediate perceptual or affective variables	Higher-order perceptual or affective variables
ESS	regularity/irregularity	goodness
number of angles	softness/sharpness	attractiveness
number of crossings	simplicity/complexity	beauty
etc.	etc.	etc.

First-order pattern psychophysics

Second-order pattern psychophysics

First-order and Second-order Pattern Psychophysics in the Study of Pattern Goodness

In investigating pattern goodness, dot patterns have often been employed, and ESS has been known to be a useful predictor of goodness, since Garner and Clement's (1973) research. Imai (1977) has also investigated pattern goodness based directly on the cognitive transformation structure of patterns. These studies can well explain the goodness ratings of dot patterns, while several studies reported that there are unignorable individual differences in goodness ratings (Matsuda, 1978; Otsuka, 1984).

In order to elucidate the internal criteria involved in pattern goodness, Gyoba, Seto, and Ichikawa (1985) asked 20 participants to rate 48 dot patterns on 25 scales of adjective pairs describing fundamental perceptual or affective properties of the dot patterns. By orthogonal principal-factor solution and varimax rotation, four factors were extracted. The first factor accounted for 51.8% of the total variance, in which coherency, regularity, and

complexity scales had high factor loadings. Thus, the first factor represents figural cohesiveness. As indicated in Figure 1, the factor scores for stimulus patterns for this factor are in line with their cognitive transformation structures proposed by Imai (1977). The remaining three factors could be regarded as evaluation, activity, and potency, based on the terminology of Osgood, Suci, and Tannenbaum (1957). These analyses correspond to first-order psychophysics.

Next, Gyoba, Seto, and Ichikawa (1985) investigate the relationships between the obtained factors and the goodness ratings of dot patterns measured in the study of Mastuda (1978). The first factor (figural cohesiveness) showed a very high correlation to the goodness ratings, and there were no large individual differences in this tendency. In contrast, the second factor (evaluation) did not indicate a high correlation to the goodness ratings. As can be seen from Figure 1, the factor scores for the second factor show an inverted-U shaped function for the transformation structure (namely, pattern goodness). This implies that some participants favored the good (cohesive) patterns, while the others preferred the bad (disorganized) ones. Therefore, it can be considered that the goodness ratings are stable and consistent when the participants judge them based mainly on the first factor (figural cohesiveness), while the ratings would include larger individual differences, depending on the confoundedness of the second factor (evaluation) with the goodness ratings. These considerations are brought to light by second-order pattern psychophysics.
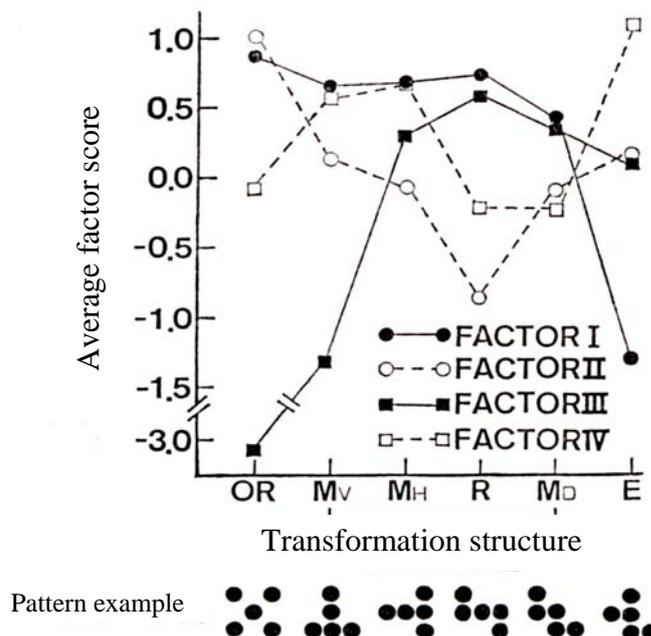

Fig. 1. The relationships between the transformation structure of dot patterns and the obtained factor scores. OR indicates the patterns that are invariant for all the transformations. Mv, MH, and MD signify the patterns that are invariant for only one of the mirror-image transformations on the vertical, horizontal, and diagonal axes, respectively. R corresponds to the pattern invariant for the rotation transformation of 180°. E signifies the pattern that is invariant for none of the transformations.

First-order and Second-order Pattern Psychophysics in the Study of Facial Attractiveness

Some of the recent studies of facial attractiveness have concentrated on the characteristics of the average facial configurations generated by computer graphics. It has been reported that consistent deviations from averageness can lead to increased attractiveness for both male and female faces (Perrett et al., 1998). These studies have shown that feminization rather than sex exaggeration in itself tends to be perceived as attractive in both male and female faces. They explained the effects of feminization in relation to personality attributes, such as warmth, honesty, and a willingness to invest in offspring, in contrast to masculinized male faces, which elicit negative personality attributes (coldness, dominance, dishonesty, etc). However, Meyer and Quong (1999) pointed out that the effects of feminization need to be argued carefully on the basis of biological, geometrical, and psychological aspects. According to them, geometrically feminized faces signal youthfulness more strongly than biological femininity.

In order to investigate the confoundedness problem, Ishi, Gyoba, Kamachi, Mukaida, and Akamatsu (2004) created not only feminized Japanese faces but also juvenilized faces by morphing between average male and female adult faces or between average male (female) adult and boy (girl) faces. They measured the attractiveness of these faces by the ranking method. The obtained attractiveness scores were analyzed by multiple regression analyses, using the two transformation ratios as predictive variables. In the case of male faces, the regression was fairly good ($R^2 = 0.68$), and the standardized partial regression coefficients (bs) for feminization and juvenilization ratios were both significant (0.50 and 0.65, respectively). For the female faces, a significant regression ($R^2 = 0.27$) was also obtained, but b for juvenilization was more significant and larger than that for feminization (0.25 and 0.45, respectively). These regression analyses showed that juvenilization could be a stronger predictor of attractiveness than feminization, as implied by Meyer and Quong (1999). However, these results are based on direct pattern psychophysics, which describes the relationships between quasi-physical variables and a higher-order affective variable (Table 1). In contrast, the following first-order and second-order pattern psychophysics reveal different aspects of the feminization and juvenilization effects on facial attractiveness.

Ishi et al. (2004) also analyzed the facial impressions of feminized and juvenilized faces by the semantic differential method (Osgood et al., 1957), using 18 adjective scales. The obtained data were analyzed by the orthogonal principal-factor solution method and rotated by the varimax method. As results, three important factors were extracted and named: "Mildness" (representative adjectives: gentle and warm), "Elegance" (beautiful and charming), and "Youthfulness" (childish and young). Then, the attractiveness scores were analyzed by multiple regression analyses, using the scores for the three factors as predictive variables. The regression was significant both for male faces ($R^2 = 0.73$) and female faces ($R^2 = 0.38$). The obtained standardized partial regression coefficients (bs) showed that the contributions of Mildness and Elegance were relatively large compared to that of Youthfulness (for male faces, 0.33, 0.59, and 0.19 for Mildness, Elegance, and Youthfulness, respectively; for female faces, 0.27, 0.35, and 0.14, respectively). This suggested that the Mildness and Elegance factors,

rather than Youthfulness factor, influence facial attractiveness more effectively in the second-order psychophysical analysis.

Then, we calculated the mean scores for the male adult, female adult, girl, and boy faces (21 images each) for the three factors and plotted the scores in two-dimensional spaces with the labels Male adult, Female adult, Boy, and Girl, respectively. We also plotted the male, female, boy, and girl average faces (M100, F100, B100, and G100, respectively), together with the six most attractive faces (mb60, mb70, mb80, fg60, fg80, and fg70) on the basis of their factor scores. For example, the face image called mb60 was morphed so as to have 60% male adult image properties mixed with 40% boy characteristics, while fg60 had 60% female adult image properties mixed with 40% girl characteristics. Figure 2 represents the locations of these faces in the Elegance － Youthfulness factor space. The score for Girl for the Youthfulness factor is the highest among those for the average faces, followed by those for Boy, Female adult, and Male adult. These characteristics are also found for the average faces: G100, B100, F100, and M100. Interestingly, in this space, both the male and female attractive faces (mb60, mb70, mb80, fg60, fg80, and fg70) are located precisely on the line that connects Male adult and Female adult, and both shift in the more feminine direction. These findings suggest that both male and female attractive faces contain augmented characteristics of femininity in these psychological factor spaces, in spite of the fact that they were rendered by juvenilized transformation. Such a psychological enhancement of femininity, not the response to the juvenile impression in itself, may be responsible for the consistent deviation from averageness to increase attractiveness in both male and female faces.
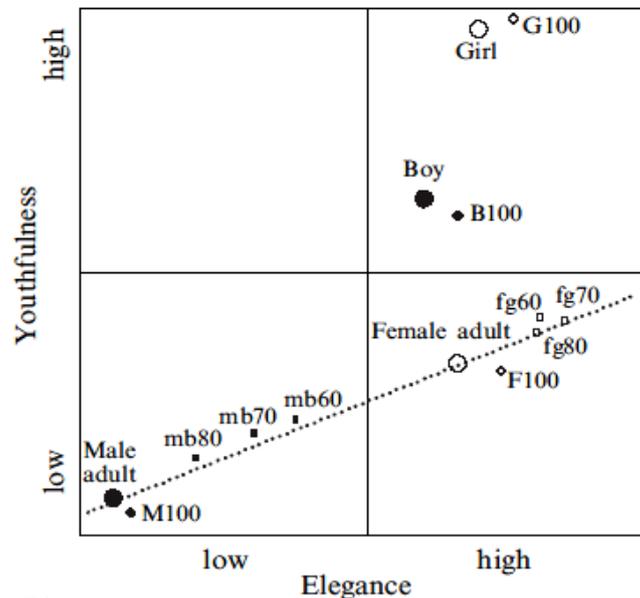

Fig. 2. Plotting attractive faces on the factor space of facial impression. The horizontal axis indicates the Elegance factor score; the vertical axis, the Youthfulness factor score. The labels of Male adult, Female adult, Boy, and Girl show the means of factor scores for Male adult, Female adult, Boy, and Girl faces, respectively. For the other labels (like M100 and mb80), refer to the text. The dotted line is assumed to show a psychological continuum between Male adult and Female adult facial impressions.

General Discussion

In the present study, a tentative taxonomy of first-order and second-order pattern psychophysics was proposed and their effective applications were introduced, with a focus on pattern goodness and facial attractiveness research.

Basically, both judgments have similar aspects. They are based on relatively higher-order cognitive and affective processes and are affected by multiple intermediate factors, which are produced internally and autonomously, as responses to the stimuli containing complex stimulus variables. In the case of pattern goodness, the figural cohesiveness mainly determines the goodness judgments, while the confounding effect of the evaluative factor would produce large individual differences. For facial attractiveness, the enhancement in femininity, which can be characterized by multiple factors such as Elegance, Mildness, and Youthfulness or their well-balanced combination, and not the juvenilization itself, is the exact source of attractiveness.

Using direct pattern psychophysics, which describes the relationships between quasi-physical variables and higher-order affective variables without intermediate variables, cannot result in such precise findings, since it leaves most dynamic internal interactions in a black box.

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