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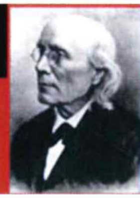

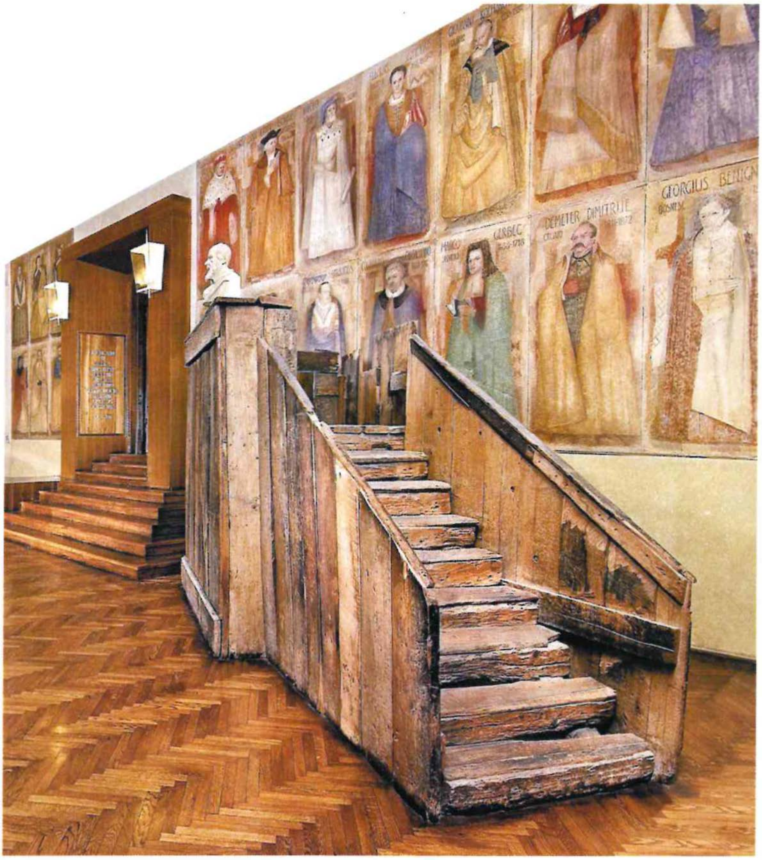

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EXPERIMENTAL PHENOMENOLOGY AND PHENOMENOLOGICAL PSYCHOPHYSICS: THE PERCEPTIONS OF CONTRARIES

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Abstract

By dealing with the issue of whether spatial contraries (high/low, large/small, wide/narrow, and long/short) are unidimensional, it will be shown how the initial definition of Phenomenological Psychophysics (Kubovy & Gephstein 2002) can be further developed to match both the requirements of a phenomenological criterion used in the selection of stimuli and the application of methods for the quantification of the constructs studied.

An analysis of contrariety as a perceptual relationship, developed in the framework of the Experimental Phenomenology of Perception (Bianchi & Savardi, 2008), has led to the identification of new methods for the definition of the metrical and topological structure of 37 spatial contraries (Savardi & Bianchi, 2000; Bianchi, Savardi, & Kubovy, submitted). The methods used have been cited (Kubovy, 2003) as an example of the application of Phenomenological Psychophysics (Kubovy & Gepshtein, 2002).

Phenomenological psychophysics (Kubovy & Gepshtein, 2002) differs from traditional psychophysics in the type of task used in experiments (Fig. 1): "The experimental phenomenologist strives to devise experimental conditions such as to make the report as close as possible to how observers would describe their experiences outside of the laboratory, but in a highly controlled environment. (…) In traditional psychophysics the natural perceptual experience is transformed (...) by asking observers to judge certain aspects of the stimulus, which engages mechanisms normally not involved in the perception of natural scenes." (p. 18)

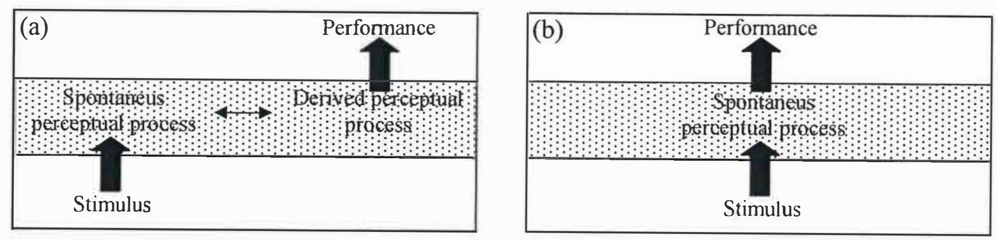

Fig. 1. Comparison of the processes that take place in observers engaged in Traditional (a) and Phenomenological (b) Psychophysical procedures (adapted from Kubovy & Gephstein, 2002).

Both traditional and phenomenological psychophysics, when describing the psychometric function involved in assessing the probability of a response to a variation in physical stimulus, typically make reference to the phi-gamma hypothesis (Urban, 1908), the phi-log gamma hypothesis (Thurstone, 1928) or the "neural quantum theory" (Stevens, Morgan & Volkmann, 1941). In the 90s, some works developed by scholars of psychophysics in Padova, Italy (Vidotto, Robusto & Zambianchi, 1996; Burro, 2009; Burro, Sartori & Vidotto, 2009) put forward the notion that quantification of the relationship between stimulus and judgment might be dealt with according to the rules of "fundamental measurement" (Campbell, 1920;

Luce, Krantz, Suppes & Tversky, 1990). To simplify somewhat the complexity of the discussion, we can say that an objective measurement can be made if the empirical data gathered are described by a mathematical model that has three "fundamental" properties: linearity, stochastic independence, and specific objectivity. It is possible to sum up these three properties with the term "concatenation", which guarantees the unidimensionality of the continuum studied: if you add (or concatenate) to an object of mass 1 a second object of mass 2, a third object is obtained whose mass is equal to the first two added together. As banal as it may seem to a physicist, this proposition is elusive to the psychologist. How can you concatenate two types of motivation, two types of intelligence, two perceptual abilities or two emotional states? However, a fundamental measurement is possible even when concatenation is not: this is where "conjoint measurement" comes in (Luce & Tukey, 1964). In the framework of psychophysics (both traditional and phenomenological), the theory of conjoint measurement says that a performance (P) is due to the conjoint effect of two parameters: a characteristic of a subject (B) and a characteristic of a stimulus (D). It follows that every performance is a multiplicative transformation of B and D, that is:

$$P_{ni} = \frac{B_n}{D_i}$$

Using a logarithmic conversion the above formula can be converted into a linear transformation

$$\lambda_{ni} = \beta_n - \delta_i\,,$$

$$\lambda_{ni} = \ln(P_{ni}), \beta_n = \ln(B_n), \delta_i = \ln(D_i)$$

β_n is also called "subject value scale" and corresponds to the position of the subject (expressed in a logit scale) along the measured continuum; δ_i is also called "stimulus value scale" and corresponds to the position of the stimulus along the same continuum of the measured variable (again, in logit scale). For example, in the case where the task consists of determining the discriminative ability of a group of subjects, β_n represents the discriminative ability of the nth subject and δ_i the difficulty of the ith stimulus to be discriminated. Discriminative ability and difficulty can be represented along the same continuum, as shown in figure 2 (in this figure it is clear that, for example, the subject with ability β_4 is able to discriminate difficult stimuli δ_1, δ_2 and δ_3, but not δ_4 and δ_5.

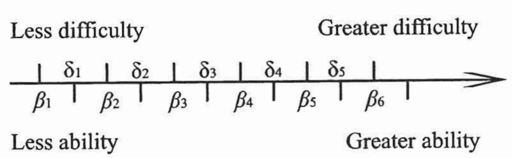

Fig. 2. Two dimensional graphs of stimulus/subject relationships (in logit scale).

It is relatively easy to pass from the above mentioned linear transformation to the definition of a mathematical model that specifies the probability of obtaining a certain discriminative performance in relation to the scalar values β_n and δ_i:

$$p\{\lambda_{ni} = w_{ni} \mid \beta_n, \delta_i, w_{ni} = (0,1)\} = \frac{e^{w_{ni}(\beta_n - \delta_i)}}{1 + e^{(\beta_n - \delta_i)}}$$

This expression is the formalization of the simple logistic model, which is the basis of the family of Rasch models (Rasch, 1960; Wright & Masters, 1982; Andrich, 1988a).
The aim of this work is to present an application of this scaling procedure to a phenomenological

psychophysical task. In particular, we studied whether bipolar judgments of height, size, width and length (*high/low*, *large/small*, *wide/narrow*, and *long/short*) referred to opposite scales on the same continuum. This is an important issue in cognitive science which has to do with the formalization of the psychological shape of dimensions.

Method

In three studies (see Bianchi, Savardi, Burro, submitted) independent ratings of *high/low*, *large/small*, *wide/narrow*, and *long/short* were elicited with adult participants looking at photographic representations of various objects (Study 1), real life objects (Study 2) and spatial extensions in object-independent conditions (Study 3).
In all three studies it was explained that the task was to rate the extent to which the target properties were present, using a 7-point scale for each stimulus. A score of 6 indicated that the property was maximally evident and 0 that it was not manifested at all. The order of the target properties was randomized between participants, but in any case we ensured that judgments referring to two contrary properties (e.g. *wide* and *narrow*) did not immediately follow each other.
Stimuli. In study 1 and 2 we used 24 everyday objects, covering a broad range of sizes (from a dice to a the nave of a church). In study 3 we used two planks of wood on the ground, one of which was in front of the observer and the other was moved into 24 different positions (from 40 cm to 960 cm, at intervals of 40 cm) along the sagittal axis (for *long-short*) and the coronal axis (for *wide-narrow*).

Results and Discussion

In order to test the unidimensionality of these spatial opposites, we applied Andrich Extended Rating Scale Models (RSM, Andrich, 1988b), which belongs to the family of Rasch Models, in addition to factor analysis. The three studies consistently showed that the variance in data is not compatible with a single continuum underlying the two series. The PCAs conducted on the raw judgments of the two opposite properties (one of which reversed) demonstrated that 5 PCs needed to be extracted to account for a percentage of total variance ranging from around 60% to 80% in all three studies. In any case the PCs with higher eigenvalues (and sometimes also others with smaller eigenvalues) showed exclusive or almost exclusive loadings *for one and not the other* series of judgments. The application of the Andrich Extended RSM allowed us to make some additional verifications.

Stimuli (and participants) fall along continua and are well distributed along each continuum

For each of the 8 target properties, it was verified that the Infit Mean Square for each stimulus (and each participant) fell inside the critical range (0.75 < Infit Mean Square <1.33). This meant that the model-data fit was guaranteed and therefore that stimuli and participants could be scaled along a linear continuum, one for each of the 8 target properties. We further tested the power of test of fit by looking at how well the stimuli (and participants) were distributed along each of the 8 continua. Testing whether the set of stimuli (and the sample of participants) was homogeneously distributed along the continuum was relevant in order to exclude the event that the lack of unidimensionality between the two opposite scalings (eventually found in the next step of the analysis) was due to the idiosyncratic behavior of some of the stimuli or participants. The Item separation index and Person separation index (which varies from 0 to 1), were excellent for all of the target properties, thus confirming that there was no anomalous behavior for judgments of some of the items or of some of the participants.

The non-unidimensionality of opposite scales

In order to verify whether judgments for the two opposite properties lay on the same continuum, we worked on the δ values obtained from the Andrich Extended RSM (that is on the scalings of the set of stimuli according to the degree to which they manifest the target property). The scalings of the δ values for the two opposites properties were equated by applying a transformation suggested by Wright and Stone (1979, pp. 94-95) and Bond and Fox (2001) in order to determine whether two scalings comply with an identity function (within the accepted 95% confidence band). According to this transformation, when two interval scales lay on the same latent continuum, the slope of the linear function representing the data is 45°. Since we were working with opposite properties, we matched "straightforward" judgments for one property and "reversed" judgments for the other (as for the PCA): if the two interval scales (e.g. the scale of "high" and that of "low", with the latter reversed) lie on the same latent continuum, the slope of the linear function representing the data should be around 45°. As shown in Figure 2 where the scalings of the items according to the two opposite properties (referred to study 1) are represented, no identity relationship was found for any of the pairs of properties examined. The data always fell outside the confidence band (Fig. 3, the area between the hatched lines). The same was found for study 2 and 3, for all the pairs of opposite properties analyzed.

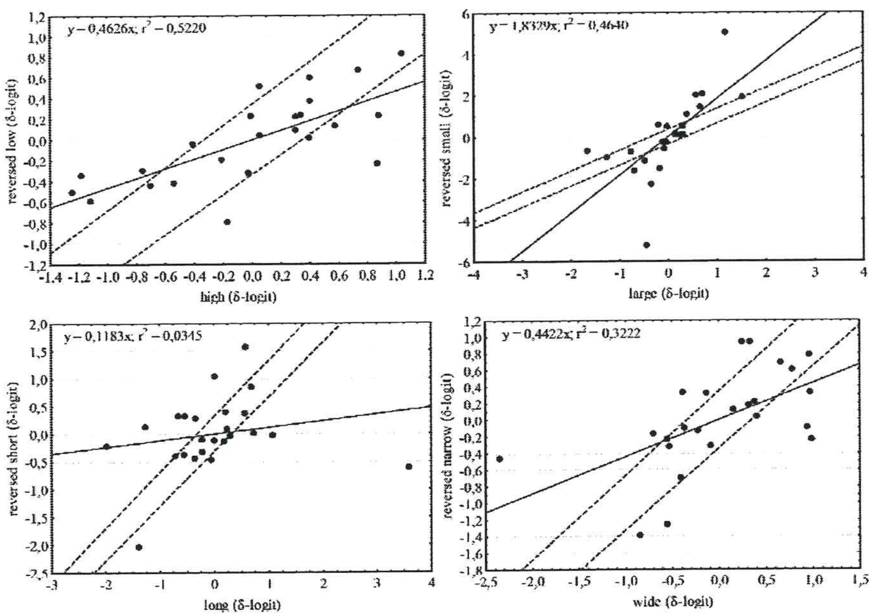

Fig. 3. The relationship between *high/low*, *large/small*, *wide/narrow* and *long/short* (in δ_i logit), according to the results of study 1. In each graph the area between the broken lines represents the area where the hypothesis that the two scales measure the same characteristics is accepted (95% confidence band).

Final considerations

We do not intend to discuss here either the possible explanation of these results or their potential impact for psychologists interested in spatial perception and cognitive models of opposites and dimension (for this see Bianchi, Savardi, Burro, submitted). We would rather spend time on

some final considerations concerning why this is an example of phenomenological psychophysics and what the advantages are of analyzing these data using Rash Models.

Rasch Models enabled us to concentrate on the scalings of the stimuli (δ) and not on the scaling of participants (β). In saying that we focused on the scalings of the stimuli, we are not saying that we were interested in analyzing the physical properties of stimuli, but in their phenomenological characteristics, i.e how they appear to the observer. In effect, the perception of objects as being *low* or *high* is a genuine psychological fact, as is the perception of movements as either *fast* or *slow*. Indeed, in terms of physics, objects are not *low* or *high* but extend *x* centimeters and movements are not *fast* or *slow*, but simply cover *x* meters per second. Therefore, studying the scalings of objects based on the degree of "highness" and "lowness" which is perceived means measuring phenomenological data. According to the prescriptions of phenomenological psychophysics (Burro, 2009; Kubovy, 2003; Kubovy & Gepshtein, 2002), the stimuli used in the study were selected for their difference in size from a phenomenological point of view and not on the basis of their physical size. Physical size was never considered in our three studies. Our purpose in fact was not to construct classic psychophysical functions between physical scalings (e.g. length in cm) and perceptual scalings (perceived degree of length), but to determine the phenomenological psychophysical functions matching two perceptual scalings (the perceived degree of *length* and perceived degree of *shortness*). The item separation index allowed us to control the distribution of the stimuli along the variable studied and therefore to test whether the stimuli used were a representative sample expressing the different perceptual sizes of objects.

Situations exist in which traditional psychophysics cannot be used in as much as the physical continuum Φ is not really available. For example, "measuring perceived grouping is fundamentally different from measuring perceived size or perceived distance, which have well-defined objective measures against which people's behavioral reports can be compared for accuracy. (...) Can perceptual organization be studied by embedding it in an experimental task for which responses can be judged to be correct or incorrect (i.e. a traditional psychophysical task)? This involves (...) changing what is actually being studied from subjective grouping to something else" (Kubovy & Gepshtein, p.18).

Take, in our case, the contrary dimensions referring to *high* and *low*: these dimensions exist only on a phenomenal level, that is, there is no unit of specific physical measurement to distinguish the two and to allow for their quantification. In fact, a physicist would speak of a stimulus Φ_1 that, for example, has a height of 3 cm, or of a stimulus Φ_2 with a height of 6000 cm, but centimeters do not describe the *experience* of *high* or *low:* if we say simply "centimeters", we immediately understand that we are speaking of a length or a height, but we cannot understand if the stimulus is *high* or *low*. Units of measurement are those parts of a continuum for which value 1 has been conventionally attributed. If a unit of measurement is "a portion of value 1" on continuum A, it cannot be "a portion of value 1" on continuum B at the same time, unless A and B are the same continuum. It follows that length, on the one hand, and *high-low,* on the other, cannot have the same unit of measurement in that the term "length" refers to a physical continuum, while the terms *high* and *low* refer to phenomenal continua , and physical and phenomenal descriptions are certainly not the same. If, in order to describe the relationship between *high* and *low,* we were to carry out a classical psychophysical analysis in terms of centimeters, this would lead to an undesirable psychophysical function that uses units of length in order to describe phenomenal units (*high* and *low*).

A possible solution can be found by using phenomenological psychophysics which is intended here as the creation of laws of connections between "scalar values Ψ of subjects" (β_n) and the "scalar values Φ of stimuli" (δ_i). Phenomenological psychophysics allows for:

1. a quantification that measures characteristics of both stimuli and subjects (scalar values β_n and δ_i), based on a concept of fundamental measurement. According to Wright & Stone,

1999, no scientific method is complete unless it is based on a concept of fundamental measurement;

2. the construction of a psychophysical function even if the physical continuum is not actually available (as in the case mentioned of "*perceived grouping*" and *high-low* contraries), in that the traditional psychophysical function $\Psi = f(\Phi)$ becomes the function $\Psi = f(\delta_i)$.

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