Acta Psychologica 149 (2014) 52–59

Contents lists available at ScienceDirect

Acta Psychologica

journal homepage: www.elsevier.com/locate/actpsy

Properties of the size–weight illusion as shown by lines of subjective equality

Michele Vicovaro, Luigi Burigana *

University of Padova, Department of General Psychology, Italy

ARTICLE INFO

Article history:
Received 26 March 2013
Received in revised form 27 February 2014
Accepted 3 March 2014
Available online xxxx

PsycInfo classification:
2300 Human Experimental Psychology
2320 Sensory Perception
2200 Psychometrics & Statistics & Methodology
2260 Research Methods & Experimental Design

Keywords:
Size–weight illusion
Multisensory process
Integration model
Constant-stimuli method
Order effect

ABSTRACT

We studied the size–weight illusion through comparative judgments. The experiment had two direct aims: to verify whether the relative contribution of size to apparent heaviness can differ for different stimulus sets, and to verify whether that contribution can differ for different methods of comparing two objects (consecutive vs. simultaneous weighing). Thirty university students participated. Results show that the relative contribution of size depends on stimulus set, but is independent of the method used for comparing objects. The first finding implies that a linear model cannot describe the integration of size and weight information in the illusion; the second finding is evidence for the low-level character of the integration process.

1. Introduction

A typical description of the *size–weight illusion* is as follows: "Two objects of equal weight may not appear equally heavy if they are of different size, the smaller of the two usually appears to be heavier. This so-called 'size–weight illusion' is exemplified by the old catch, 'Which is heavier, a pound of lead or a pound of feathers?' Although a pound is a pound, the lead weight invariably feels heavier, as much as three or four times heavier." (Cross & Rotkin, 1975, p. 79). In line with this description, in our study we use the terms *size*, *weight*, and *heaviness* to refer to the physical size (volume) of an object, its physical weight, and its apparent (perceived) weight. What makes the illusion a surprising fact is that heaviness depends on size, in a negative way. Thus, a measure of the lessening effect of size on heaviness may be taken as a measure of the magnitude of the illusion.

The size–weight illusion is a *multisensory* phenomenon, as it depends on two stimulus properties (size and weight) each of which involves different sensory modalities. Starting with the experiments of Charpentier (1891) (see Nicolas, Ross, & Murray, 2012), the phenomenon has been studied in a variety of experimental conditions: for example, researchers have compared the effect of size when it is available only in the visual, only in the haptic, or in both sensory modalities (Amazeen & Jarrett, 2003; Ellis & Lederman, 1993), and the effect of weight when an object is lifted by grasping it, or by using a hook or handle (Amazeen, 1997; Anderson, 1970; Masin & Crestoni, 1988).

The theory of the illusion has developed in various directions. One is the construction of psychophysical models representing how the size and weight information may combine in determining apparent heaviness; simple additive or multiplicative models have been proposed (Anderson, 1970; Sjöberg, 1969), as well as models of higher complexity (Cross & Rotkin, 1975; Gregson & Britton, 1990; Stevens & Rubin, 1970). Another direction aims at finding higher-order properties of the stimulus – stimulus invariants – capable of specifying perceived heaviness (e.g., physical density discussed by Huang, 1945; rotational inertia defined by Amazeen & Turvey, 1996). A third direction moves from the assumption that the size–weight illusion is a contrast effect – contrast between felt and expected weight – and explores the manners in which such a contrast may take place (Buckingham & Goodale, 2010; Davis & Roberts, 1976; Loomis, 1907; Nakatani, 1985). A fourth and more recent theoretical direction views the size–weight illusion as a notable case to illustrate possible dissociations between perception

* Corresponding author at: Università di Padova, Dipartimento di Psicologia Generale, via Venezia 8, I-35131 Padova, Italy. Tel.: +39 49 8276668, +39 49 8959112; fax: +39 49 8276600.
E-mail addresses: vicovaro85@gmail.com (M. Vicovaro), luigi.burigana@unipd.it (L. Burigana).

http://dx.doi.org/10.1016/j.actpsy.2014.03.001
0001-6918/

system and action system (Brayanov & Smith, 2010; Flanagan & Beltzner, 2000; Flanagan, Bittner, & Johansson, 2008; Grandy & Westwood, 2006). The illusion has also been compared with other phenomena depending on the same stimulus properties: for example, the subjective impression of mass of objects when mass is involved in terms of inertial forces rather than gravitational forces (weight) (Plaisier & Smeets, 2012).

In our study we consider situations that are typical of the "traditional size–weight illusion experiments" (Ellis & Lederman, 1993, p. 316). Specifically, in each experimental trial we present the observer with two objects, which the observer can see and will grasp and lift. The observer's task is to compare the heaviness of the two objects. The data are used for two aims described hereafter.

1.1. First aim, concerning integration of stimulus information

One of the main research directions mentioned above is about descriptive psychophysical models of the size–weight illusion. A simple model of this kind is based on the equation

$$H = \beta_S \times S + \beta_W \times W. \quad (1)$$

Term H stands for the apparent heaviness of an object; S and W are measures of the physical size and weight of the object; and β_S and β_W are (unknown) coefficients specifying the relative contribution of S and W in determining H (they are the parameters of the model). Eq. (1) has a linear form; it presumes that stimulus factors S and W contribute additively to determine the psychological property H, in rates specified by coefficients β_S and β_W. These coefficients are not known a priori, but we may generally assume that $\beta_W > 0$ (heaviness increases with physical weight), $\beta_S < 0$ (heaviness decreases with physical size, as shown by the size–weight illusion), and the absolute value of β_S is a measure of the magnitude of the illusion. Terms S and W are physical variables, and may be represented on the main axes of a plane, which is the *stimulus space* of our study; any object having definite size s and weight w may be represented as the point of coordinates (s,w) on that plane (see Fig. 2).[1] Linear models of the size–weight illusion have received support in some studies (Anderson, 1970; Dunn & Harshman, 1982; Masin & Crestoni, 1988), and criticism in others (Birnbaum & Veit, 1974; Cross & Rotkin, 1975).

The first aim of our present research is to contribute to the *descriptive psychophysical modeling* of the size–weight illusion. We will take the linear model (1) as a basic paradigm to be directly tested by experiment, but the data we will collect may also allow us to draw conclusions about other models associated to the illusion.

A distinctive feature of our study is the method we use for testing model (1). Two aspects of the method are worthy of note. The first is that we consider three sets of stimuli only differing in their location on the stimulus plane (the "small-heavy," "central," and "large-light" sets represented in Fig. 2), obtain a sample of individual estimates of the parameters in the model for each stimulus set, and then compare the three samples of estimates. Should these samples be significantly different from one another, then we would infer that there are *no single* values of the parameters such that the model fits the data over the *entire* stimulus region examined (i.e., the region covered by dots in Fig. 2). This would imply that model (1) is implausible when referred to the population of objects on which the size–weight illusion may be illustrated. In other words, we test the plausibility of model (1) by testing the *invariance* of its parameters in the stated conditions.

The second noteworthy aspect of our method is the psychophysical technique we use for collecting the data. Most studies on descriptive models of the illusion have been conducted by applying psychophysical methods that require numerical responses from the participants (e.g., magnitude estimation of heaviness in Sjöberg, 1969 and Cross & Rotkin, 1975; category rating of heaviness in Anderson, 1970 and Masin & Crestoni, 1988; estimating or rating differences in heaviness in Ross & Di Lollo, 1970 and Dunn & Harshman, 1982). Unlike these studies, in our experiment we use a variant of the psychophysical method of "constant stimuli," setting the participant a three-choice discrimination task, so that our data result from a *scale-free* technique (Birnbaum & Veit, 1974, p. 277; explained in Section 2.4).

1.2. Second aim, concerning method of comparison

As regards the method of comparing the heaviness of two objects, an elementary distinction is that between the *consecutive* method (the objects are weighed by the same hand in two consecutive moments) and the *simultaneous* one (the objects are weighed separately by two hands at the same time). Among the experiments on the size–weight illusion that required pair comparisons, some applied only the consecutive method (e.g., Ellis & Lederman, 1993; Sjöberg, 1969), and others only the simultaneous one (e.g., Birnbaum & Veit, 1974; Nakatani, 1985).

The second aim of our research is to verify whether this distinction between methods has any influence on the properties of the size–weight illusion. In order to make this test possible, in our experiment we applied *both* methods of comparison to the same stimuli and the same participants.

The theoretical argument underlying this question is the following. When two objects are compared in terms of heaviness, there are four stimulus properties on which the result mostly depends, i.e., the size s and weight w of one object, and the size s' and weight w' of the other. If the comparison is via the consecutive method, then these properties are available in two pairs (s,w) and (s',w') separated in time; in contrast, if the comparison is via the simultaneous method, then they become available as a quadruplet (s,w,s',w') of coexisting data. In these terms, we may hypothesize that the simultaneous method favors a *direct contrast* between the weights of the stimuli (w and w'), i.e., a selective focusing of attention on these two stimulus properties, given that they are available at the *same time* and the participant is expressly asked to compare both objects in terms of their apparent *weight*. If this were the case, then a neglect of the sizes of the stimuli (s and s') would ensue, and this would imply a weakening or failure of the size–weight illusion.

The idea that, in certain conditions, a sort of "cancellation or short-cut strategies" may take place in the evaluation of apparent weight of objects, which "would disrupt the information integration process" of size and weight, has occasionally appeared in the literature (e.g., Birnbaum & Veit, 1974, p. 281). Likewise, it has been hypothesized that manipulations of the observer's attention towards the size or weight components of the stimulus information may affect the strength of the illusion (e.g., Dunn & Harshman, 1982, pp. 36–37). Experimental results pertaining to the second aim of our study may also bear on the contrast between low-level (perceptual) vs. higher-level (cognitive) nature of the size–weight illusion, which makes a salient question in the theory of the phenomenon (Ellis & Lederman, 1993, p. 322).

2. Experiment

2.1. Design

To fulfill the first aim of our study – i.e., testing model (1) in terms of invariance of its parameters – we designed three experimental

[1] For specifying the stimuli we could refer to mass rather than weight. This option would be preferable when the size–weight illusion is compared with psychological phenomena having this characteristic: they are function of stimulus properties that are different from weight and that depend (as weight does) on the mass of bodies (e.g., inertial forces; Plaisier & Smeets, 2012). For consistency with the terminology prevailing in the literature, however, we will continue to call "weight" the basic stimulus property that intervenes (along with size) in the size–weight illusion.