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LAST BUT NOT LEAST

"Which feels heavier—a pound of lead or a pound of feathers?" A potential perceptual basis of a cognitive riddle

Jeffrey B Wagman, Corinne Zimmerman, Christopher Sorric
Department of Psychology, Illinois State University, Normal, IL 61790-4620, USA;
e-mail: JeffreyWagman@ilstu.edu
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Abstract. "Which weighs more—a pound of lead or a pound of feathers?" The seemingly naive answer to the familiar riddle is the pound of lead. The correct answer, of course, is that they weigh the same amount. We investigated whether the naive answer to the riddle might have a basis in perception. When blindfolded participants hefted a pound of lead and a pound of feathers each contained in boxes of identical size, shape, and mass, they reported that the box containing the pound of lead felt heavier at a level above chance. Like the size – weight illusion, the naive answer to the riddle may reflect differences in how easily the objects can be controlled by muscular forces and not a perceptual or cognitive error.

"Which weighs more—a pound of lead or a pound of feathers?" The seemingly naive answer to this familiar riddle is the pound of lead whereas the correct answer is that they weigh the same amount. The naive answer may reflect robust misconceptions about weight and mass (ie a 'cognitive error'). For example, children and adults have pre-existing beliefs that heavier objects fall faster and sink faster than lighter objects. Moreover, such beliefs often persist even after participants conduct experiments and observe evidence to the contrary (Chinn and Malhotra 2002; Penner and Klahr 1996; see Zimmerman 2007 for a review).

However, the naive answer may not be so naive after all. For over 100 years, psychologists have known that two objects of equal mass can feel unequally heavy depending on the mass distribution of those objects (Charpentier 1891; Seashore 1899). In particular, given two objects of equal mass, the one with the smaller volume (ie the one with the more compact mass distribution) generally feels heavier. This is the *size – weight illusion* (Jones 1986; see Murray et al 1999). Holding a pound of feathers and a pound of lead would be expected to induce such an illusion. Given a smaller volume (ie a more compact mass distribution), the pound of lead would be expected to feel heavier.

That is, instead of reflecting a cognitive error, the naive answer to the riddle may reflect how heavy the two objects might feel if actually held in the hands. We explore the potential perceptual basis of the naive answer by investigating whether a pound of lead feels heavier than a pound of feathers.

One pound (453.6 g) of lead shot was poured into a plastic bag, which was sealed and taped to the inside of the bottom panel of a 16 cm $\times$ 16 cm $\times$ 31 cm cardboard box (this panel was designated as the 'bottom' of the box), and one pound (453.6 g) of goose down feathers was stuffed into a plastic bag, which was sealed and fit snugly into an identical cardboard box. Each box was taped shut. The total weight of each box (with feathers or lead, bag, and tape) was 637.9 g.

Participants ($N = 23$) sat in a chair, put on blackened goggles, and placed the palm of their preferred hand up with their fingers relaxed. On a given trial, each box was placed on the participant's palm in succession. The participant hefted each box and reported which box felt heavier ('first box' or 'second box'). Participants hefted a given box as long as they wished and alternated between boxes as often as they wished.

There were 20 trials—10 beginning with the box containing lead and 10 beginning with the box containing feathers. Trial sequence was randomized for each participant. Participants were not informed about the number or contents of the boxes.

The box containing lead was reported as being heavier than the box containing feathers on a mean of 11.13 of the 20 trials. A one-sample, two-tailed t-test revealed that this value is significantly larger than 10, the value expected if participants were responding at a chance level ($t_{22} = 2.64$, $p = 0.015$). A Wilcoxon signed-ranks test confirmed that the proportion of participants who chose the 'lead' box more often than the 'feathers' box (73.9%) was greater than the proportion who chose the 'feathers' box more often than the 'lead' box (17.4%) and the proportion of ties (8.7%) ($z = -2.48$, $p = 0.013$).

These results show that, consistent with the naive answer to the riddle, a pound of lead feels heavier than a pound of feathers. Like the size–weight illusion (and the related material–weight illusion—Seashore 1899), this finding demonstrates that perception of heaviness is not merely the perception of mass. What other factors influence perception of heaviness? Why might a pound of lead feel heavier than a pound of feathers?

Some models of heaviness perception suggest that perceived heaviness is a combination of independent sensations of mass and size (eg Cross and Rotkin 1975). Others suggest that perceived heaviness results from a comparison of expected and actual muscle activity in lifting an object (eg Davis and Brickett 1977). However, our results seem less consistent with such models, given that (a) the boxes were identical in size, shape, and mass, and (b) participants were blindfolded throughout the experiment.

Rather, our results seem consistent with findings that perception of heaviness is a function of an object's dynamical symmetry—how its mass is distributed relative to where it is held (Turvey et al 1999). Such a property is an important contributor to the 'feel' of a hand-held object (Kriefeldt and Chuang 1979), and influences perception of a number of geometric and functional properties of hand-held objects (see Carello and Turvey 2004).

An object's dynamical symmetry determines the magnitude and direction of muscular forces required to control that object (Shockley et al 2004). All other things being equal, the more asymmetric an object's mass distribution, the more diverse the muscular forces required to control that object, and the more difficult the object is to control. Therefore, in general, objects with symmetric mass distributions feel lighter than objects with asymmetric mass distributions, even if those objects are the same mass (Amazeen and Turvey 1996). Such findings suggest that, rather than reflecting a cognitive or perceptual error, the size–weight illusion reflects sensitivity to differences in the mass distribution (and hence controllability) of the two objects held in the hands.

As regards the stimuli used in the current experiment, the mass of the feathers was distributed more or less symmetrically in the box (ie the feathers filled the box), but the mass of the lead was distributed asymmetrically along the vertical axis (ie the box was 'bottom-heavy'). Therefore the box containing lead was more difficult to control, and it felt heavier.

Our results show that, consistent with the naive answer to the riddle (when size, shape, and mass are held constant), a pound of lead feels heavier than a pound of feathers. Therefore, the naive answer to the riddle seems to have a basis in perception. Much like the size–weight illusion, rather than reflecting a cognitive or perceptual error, the naive answer may reflect sensitivity to differences in mass distribution (and hence differences in controllability) of the two objects under consideration.

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