Experimental Psychology, 1968, 77, 506-508.
SHEPARD, R. N. Recognition memory for words, sentences, and pictures. Journal of Verbal Learning & Verbal Behavior, 1967, 6, 156-163.
SPERLING, G. A model for visual memory tasks. Human Factors, 1963, 5, 19-31.
THURMOND, J. B., & ALLUISI, E. A. Choice time as a function of stimulus dissimilarity and discriminability. Canadian Journal of Psychology, 1963, 17, 326-337.
TVERSKY, B. Pictorial and verbal encoding in a short-term memory task. Perception & Psychophysics, 1969, 6, 225-233.
WICKELGREN, W. A. Acoustic similarity and intrusion errors in short-term memory. Journal of Experimental Psychology, 1965, 70, 102-108.

Weight judgment as a function of apparent density of objects*

STEPHEN P. HARSHFIELD and DORIS C. DeHARDT†
California State College, Long Beach, Calif. 90801

Five cubes of equal size and weight made of balsa wood, mahogany, aluminum, brass, and steel were ranked from heaviest to lightest in the above order by Ss who lifted each of these cubes, while Ss who ranked the cubes visually reported the reverse order, as their apparent density would prescribe. Phenomenologically the present results, which might be called a density-weight illusion, are quite similar to those of the size-weight illusion.

The familiar size-weight illusion dramatically illustrates the effect of size on the judged weight of objects (Crutchfield, Woodworth, & Albrecht, 1955). The differential effects of brightness and hue on the apparent weight of objects have also been reported (Harshfield & Shaumburg, 1964; Monroe, 1925; Payne, 1961). Harshfield and Shaumburg found that stimulus objects of equal size and weight were judged lighter in direct relation to their brightness.

In the present study the apparent composition of objects was manipulated with the expectation that cubes of equal size and weight would be judged inversely, i.e., heavier, with their apparent density. Thus, a lifted cube made of balsa wood was expected to be judged heavier than one made of, say, brass. It was predicted that cubes of equal size and weight made of balsa wood, mahogany, aluminum, brass, and steel would be ranked heaviest to lightest in that order by Ss lifting each of these cubes, but that Ss ranking the cubes visually would report the reverse order. This phenomenon of judgmental reversal might be called a density-weight illusion.

SUBJECTS

Ninety volunteers from introductory psychology classes at California State College, Long Beach, served as Ss.

APPARATUS

The stimuli were five 1½-in. cubes made of balsawood, mahogany, aluminum, brass, and steel. The cubes were bored out and/or filled with lead shot as was necessary to make each weigh 5 oz (143 ± 2 g). Masking tape covered the altered area on the bottom of each cube. A piece of beige felt covered the table upon which the cubes were placed during the experiment. Rubber glove fingers that covered to the first knuckle were used for Ss in the lifting conditions and a blindfold was used for the control group.

PROCEDURE

The 90 Ss were divided randomly into three groups of 30 each. One group, the visual group, ranked the cubes only by looking at them; another group, called the lift group, ranked the cubes after lifting while looking; a control group lifted while blindfolded. Ss in the groups involved in lifting were asked to use their dominant hands.

Each S was seated comfortably at a table and given instructions in the task which included that the cubes were to be ranked from heaviest to lightest, one through five. No ties were permitted in the judgments and no time restraint was set for the task. In the conditions involving lifting, Ss were told to lift the cubes before them, singly, working from left to right and then to start over again so that each cube would be lifted twice. Ss were told to lift only with their covered fingers (thumb and first and second fingers), to keep their elbows on the table, to lift a cube in one smooth decisive motion (for a distance of about 6 in.), and not to dangle the cube at the top of a lift but to replace it immediately. In the visual group Ss were permitted to look at the cubes as long as they liked before making their rankings. In the visual and lift groups announcement of rankings was made by S's pointing at the cube that seemed heaviest, then the next heaviest, and so on; control Ss used verbal explanations, such as "the second cube from the left is heaviest," to indicate their rankings.

Different random orders of left-to-right placement of cubes were used for all Ss.

RESULTS AND DISCUSSION

The means and standard deviations of rankings for Ss in each of the three groups are presented in Table 1. To determine the degree of inter-S agreement for Ss in each condition, Kendall's coefficient of concordance, W, was computed for each group. The results of this analysis are also shown in Table 1.

To determine whether the differences in mean ranks between each adjacent pair of cubes in each condition were statistically significant, sign tests for related samples were performed. For a particular cube pair in a particular condition the number of Ss reporting one cube heavier than the other was determined and formed the basis of the sign test on that pair. Thus, for statistical purposes, each adjacent pair was regarded as an independent comparison for Ss. The sign test results, in normal

Table 1
Means and Standard Deviations of Ranks and W's for the Five Cubes in Each Group

	Experimental Group					
	Visual $W = .746$ $p < .001$		Lift $W = .445$ $p < .001$		Control $W = .004$	
Cube	M	SD	M	SD	M	SD
Steel	1.20	.42	4.00	1.13	3.06	1.29
Brass	2.00	.65	3.70	1.02	3.20	1.22
Aluminum	3.40	.85	3.50	.95	3.10	1.32
Mahogany	3.50	.61	2.10	.81	2.96	1.52
Balsa Wood	4.70	.73	1.63	1.01	2.96	1.62

*Based on the senior author's thesis submitted to California State College, Long Beach in partial fulfillment of requirements of the MA degree.

†The authors appreciate the assistance of Henry Michalewski with the manuscript. Requests for reprints should be sent to Doris C. DeHardt, Department of Psychology, California State College, Long Beach, Calif. 90801.

Table 2
Sign Test Results (z) for All Adjacent Cube Pairs for Each Group

Cube Pair	Experimental Group Visual	Experimental Group Lift	Control
Steel-Brass	3.15*	1.66*	.19
Brass-Aluminum	4.63*	.93	.50
Aluminum-Mahogany	.56	3.51*	.56
Mahogany-Balsa Wood	4.26*	1.66*	.19

*$p < .05$

approximation form (z), are presented in Table 2.

From the Kendall analysis it is apparent that Ss in the visual and lift groups were statistically consistent in their respective rankings, while the control group exhibited only the expected random agreement in ordering. And, as was predicted, the ordering of cubes from heaviest to lightest for the visual group was steel, brass, aluminum, mahogany, and balsa wood; and for the lift group this order was precisely reversed. Only one adjacent cube pair in each of these conditions failed to produce significantly different weight judgments: the aluminum-mahogany pair in the visual group and the brass-aluminum pair in the lift group. It is fair to assume that objects identical in size and weight and made of many other materials, e.g., cardboard, granite, or plastic, would also be differentially judged as to weight.

The subjective reports of Ss after the completion of the task reflect even more strongly, perhaps, the nature of this so-called density-weight illusion. No S in the lift group indicated that he suspected the cubes were all of the same weight as he lifted them, and most Ss expressed disbelief when told this by the E. A number of the Ss were permitted to manipulate the weights after the experiment in a casual attempt to assess the intellectual contribution to the illusion. The phenomenon did not appear to diminish with repeated lifting, despite knowledge of the objective weight of the cubes.

The phenomenological similarity of the present results to those of the size-weight illusion should be mentioned. In both instances it is nearly impossible for Ss to believe that objects weighing the same could feel so different when lifted.

REFERENCES

CRUTCHFIELD, R. S., WOODWORTH, D. G., & ALBRECHT, R. E. *Perceptual performance and the effective person.* San Antonio: Air Force Personnel and Training Research Center. 1955.

HARSHFIELD, S. P., & SHAUMBURG, G. Judgment of weight as a function of brightness. Unpublished paper. California State College, Long Beach, California, 1964.

MONROE, M. The apparent weight of color and correlated phenomena. American Journal of Psychology, 1925, 36, 192-206.

PAYNE, M. C. Apparent weight as a function of hue. American Journal of Psychology, 1961, 74, 101-105.

ERRATUM

DRUCKMAN, D. Position change in cognitive conflict as a function of the cue-criterion relationship and the initial conflict. Psychonomic Science, 1970, 20 (2), 91-93.–Page 93, column 3: The sentence beginning with Summers (1968) should not have brackets around it. Page 92: column 2: the last line of the column was omitted; it should read "breakdown by cue discrepancy."