

SIMULTANEOUS USE OF DIFFERENT MENTAL STANDARDS IN MAGNITUDE ESTIMATION OF LINE LENGTH

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Abstract

Subjects making magnitude estimations of line length behave as if they were concatenating a mental standard with itself along the length being estimated. Using a 1-cm standard line (S) a chronometric analysis of magnitude estimation of line length revealed that subjects mentally concatenated S for lines up to ten times longer than S and mentally concatenated a multiple of S for lines more than ten times longer than S . Differences in mental standards and in strategies of mental concatenation account for the variation of individual exponents and the often reported deviations from unity of the mean exponent of the psychophysical function for length.

The time required to make a magnitude estimation of line length increases linearly with the length to be estimated and as the length of the standard decreases (Hartley, 1977, 1981; Reed, Hock, & Lockhead, 1983). These facts support the idea that subjects concatenate a mental standard with itself along the length being estimated. Magnitude estimates would be counts of the number of mental standards needed to entirely cover the length being estimated.

To test the constancy of the mental standard Hartley (1977) had subjects produce lines with length n times longer than that of a 1-cm standard line for $n = 1.5, 3, 4.5,$ or 6 while the senior writer of this paper did this using a 1.8-cm standard line with $n = 2, 4, 6, 8,$ or 10 . Their results were similar. Figure 1 shows those of the senior writer. The geometric mean produced multiple of the standard is represented as a function of the multiple of the standard. The line passing through the origin shows equality of produced and actual multiples of standard. The line passing through the solid circles represents a least-square fit to a straight line.

These results indicate that the length of the mental standard is constant since

$$P = k + n \cdot (S + c) = k + C + n \cdot c \quad (1)$$

with S the length of the standard, C the multiple of S , P the produced C , and k and c constant errors. In Figure 1, k is negative and c positive.

The above tests only considered ns up to 10. The following experiment tested the constancy of the mental standard for ns up to 50.

Experiment 1

Subjects and Stimuli

Ten university students served as subjects. The stimuli were black 1-mm thick horizontal lines concentric with a light gray 104×53 cm background on a NEC PlasmaSync 50MP2 monitor screen. Viewing distance was about 90 cm.

Each trial started with the phrase “ n times,” with the numeral 2, 4, 6, 8, 10, 15, 20, 30, 40, or 50 in place of n , displayed centrally at 12 cm from the upper side of the background. When the participant pressed a key this phrase disappeared and, 1 sec after, three suc-

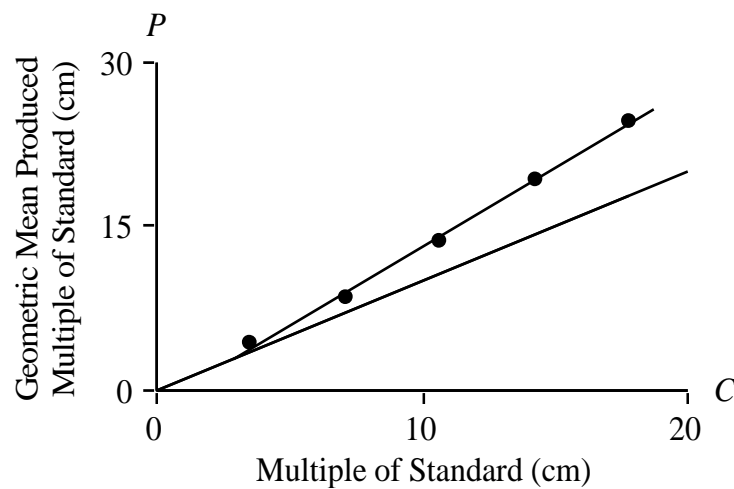


Fig. 1. Geometric mean produced multiple of standard line, P , plotted against actual multiple of standard line, C , equal to 2, 4, 6, 8 or 10 multiplied by 1.8 cm.

cessive stimuli were presented, Stimuli A, B, and C. Stimuli A and B appeared either in this order or in the reversed order. Stimulus C appeared last. The duration for Stimuli A and B and the interstimulus intervals was 1.5 sec. Stimulus C remained visible until the participant or the experimenter pressed a key.

The length of Stimulus A was 0.94 cm. At the start of each trial, the length of Stimulus B was 0.94 or 62.2 cm and the length of Stimulus C was equal to that of Stimulus B. Participants smoothly decreased or increased the length of Stimulus C by keeping pressed the left or right of two horizontally aligned keys, respectively.

For each phrase specifying n , there was a different combination of presentation orders of Stimuli A and B. Stimuli were presented twice in random order.

Procedure

At the beginning of each trial, Stimuli B and C had equal length. The participant was asked to decrease or increase the length of Stimulus C by keeping the respective key pressed continuously until this length was equal to n times that of Stimulus A—with n the number 2, 4, 6, 8, 10, 15, 20, 30, 40, or 50 specified by the phrase shown at the start of the trial—and, when necessary, by bracketing the length of Stimulus C equal to n time that of Stimulus A.

The participant pressed a key when this production was terminated. As this key was pressed, the length of Stimulus C was assigned to Stimulus B. After this assignment, the participant pressed the key again to display Stimuli A–C and judge whether Stimuli A and B were in the specified length ratio, n . The participant repeated this process as many times as needed until the most satisfactory length ratio was obtained.

Results and Discussion

Figure 2 shows the geometric mean produced multiple of the standard plotted against the multiple of the standard. Solid and open circles refer to n s in the ranges 2–10 and 15–50,

respectively. The line passing through the origin represents the straight line $P = C$. The lines passing through data points represent least-square fits to straight lines.

The slope of the straight line fitting the data points represented by filled circles did not differ significantly from 1, $t(9) = .37$. The trend of these data points and that of the data

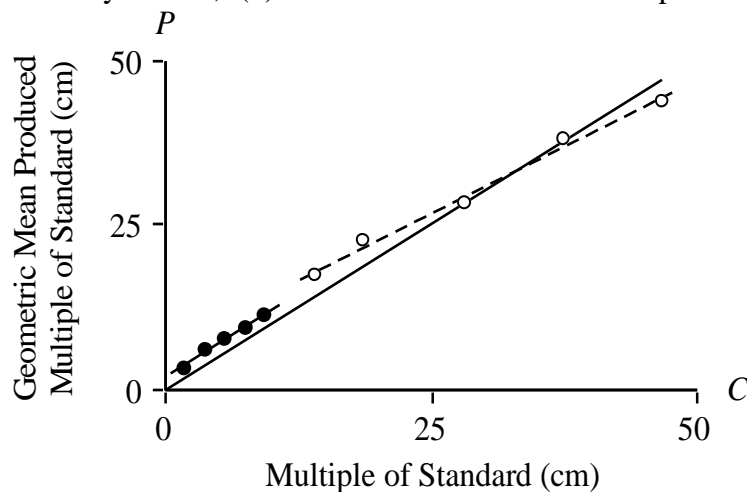


Fig. 2. Geometric mean produced multiple of standard line, P , plotted against actual multiple of standard, C , equal to 2, 4, 6, 8 or 10 (solid circles) or to 15, 20, 30, 40, or 50 (open circles) multiplied by 0.94 cm.

points in Figure 1 predict that the straight line fitting the open circles in Figure 2 should have slope 1 or higher. Instead this slope was significantly less than unity, $t(9) = 3.62$, $p < .01$.

This finding raises the possibility that subjects used different mental standards when n was 2–10 or 15–50. Differences in mental standards imply differences in duration of corresponding magnitude estimations. The following experiment tested this implication.

Experiment 2

Subjects and Stimuli

Twenty university students served as subjects. Stimuli and stimulus conditions were identical to those used in Experiment 1. On each trial the test stimulus was preceded by a 1.5-sec standard stimulus with an interstimulus interval of 1.5 sec. Test stimuli remained visible until the end of the trial. The length of the standard was 0.94 cm and that of the test stimulus was 2, 4, 6, 8, 10, 15, 20, 30, 40, or 50 cm. The series of test stimuli was presented four times consecutively each time with test stimuli in random order. Viewing distance was about 150 cm.

Procedure

The participant was asked to report how many times the standard stimulus could be contained in the test stimulus. The participant was asked to press a key as soon as he or she was ready to respond and was asked to respond verbally after this key was pressed. The time elapsed from the onset of the test stimulus to this press of the key was recorded.

Results and Discussion

In Figure 3, solid and open circles show the geometric mean estimated length plotted against test stimulus length for lengths of 2–10 and 15–50 cm, respectively. The line passing through

the origin shows numerical equality of estimated and actual stimulus lengths. The lines passing through data points represent least-square fits to straight lines.

The results indicate that subjects made magnitude estimations using different mental standards for relatively short and relatively long lengths. The straight line fitting filled

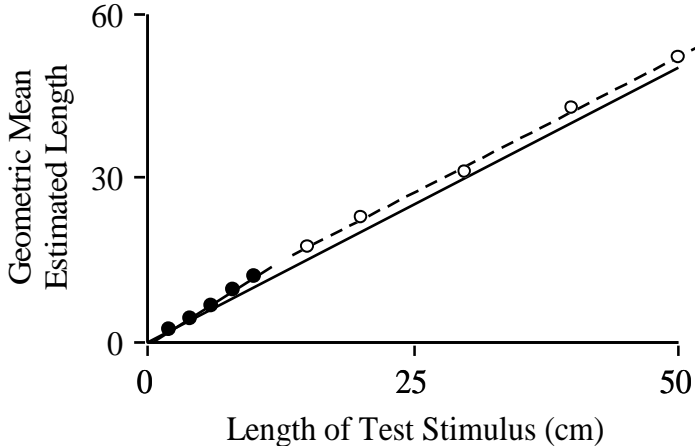


Fig. 3. Geometric mean estimated length of the test stimulus plotted against the actual length of the test stimulus.

circles had slope significantly different from unity, $t(19) = 5.32, p < .001$, and the straight line fitting open circles had slope not significantly different from unity, $t(19) = 1.06$. The exponent of the standard power function fitting the entire set of data points was 0.94.

What was the length of mental standards? For lines in the range 2–10 cm, this length was the imagined length of the 0.94-cm standard. For lines in the range 15–50 cm, the length of the mental standard could be determined by following chronometric analysis.

Figure 4 shows the geometric mean of the duration of magnitude estimation of length of test stimuli plotted against the length of test stimuli. The solid and open circles show the results for test stimuli in the ranges of 2–10 and 15–50 cm, respectively. Two lines represent least-square fits to straight lines.

These results clearly support the idea that subjects estimated line length using two different mental standards. The results for test stimuli in the range of 2–10 cm show that the time needed for adding once the mental standard to itself along the test line of 10 cm was about 0.2 sec. On the assumption that this time was independent of the length of the standard, the results for test stimuli in the range 15–50 cm show that the mental standard concatenated along these lines had a length corresponding to about 8 cm.

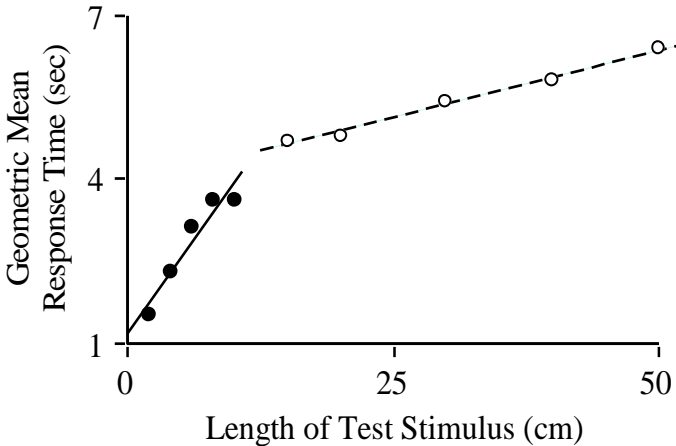


Fig. 4. Geometric mean of the time taken to produce a magnitude estimation of the length of the test stimulus plotted against the length of the test stimulus.

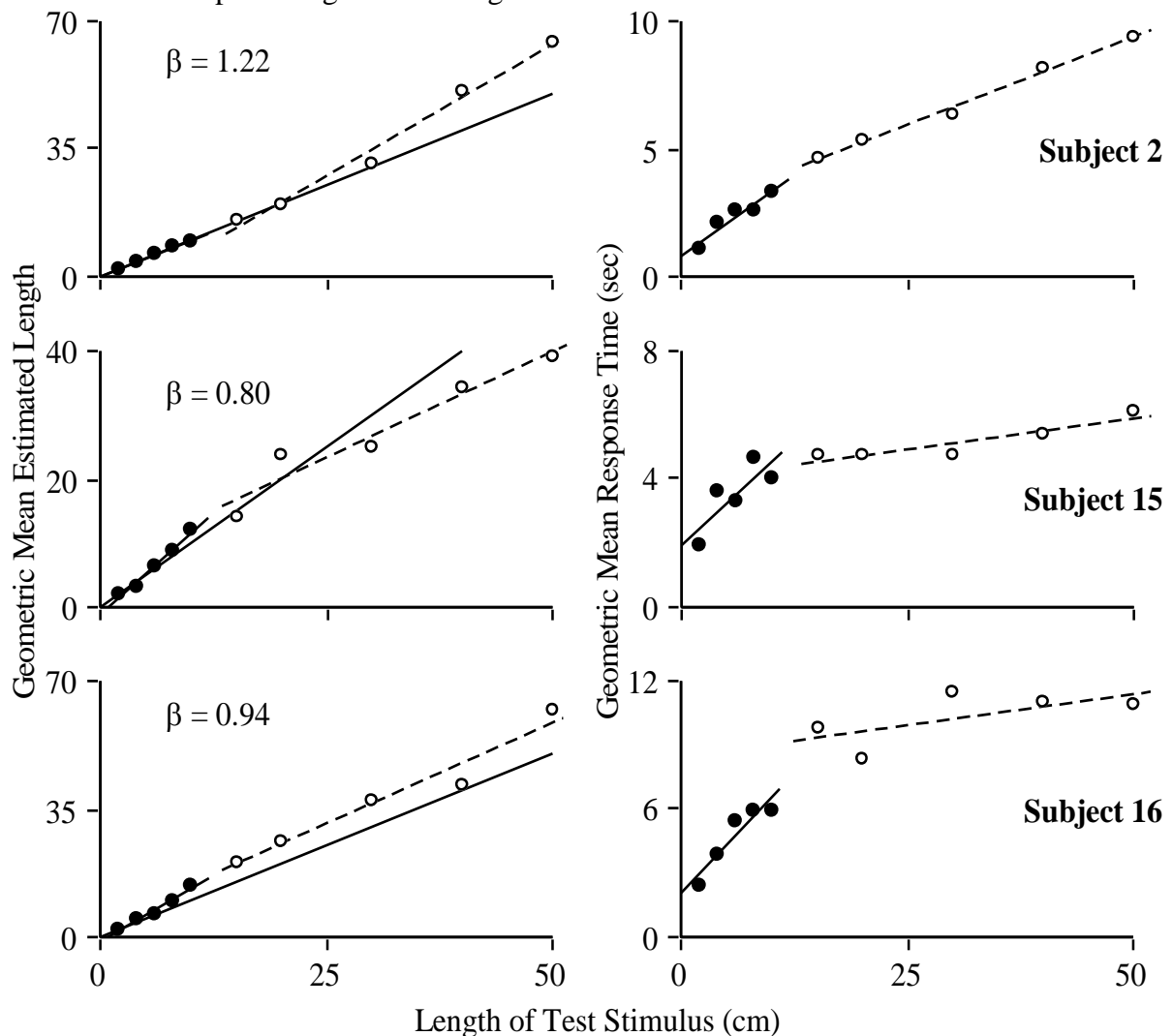


Fig. 5. Results for Subjects 2, 15, and 16. For each subject, the left diagram shows the geometric mean of estimated length of test stimulus and the right diagram shows the geometric mean of time taken to make a magnitude estimation plotted against the length of test stimulus.

Figure 5 shows examples of individual results. For each of the Subjects 2, 15, and 16, the left diagram shows the geometric mean of the estimated length of the test stimulus, and the right diagram shows the geometric mean of the time taken to execute a magnitude estimation, as a function of the length of the test stimulus.

The left diagrams report the exponent β of the standard power function fitting the whole set of magnitude estimation data points. Inspection of individual data showed that β was larger than unity for 7 subjects (exemplified by Subject 2) and was definitely smaller or barely smaller than unity for 13 subjects (exemplified by Subjects 15 and 16, respectively).

At the end of the experiment, the subjects were asked to report on possible estimation strategies. They reported several variants of the basic strategy consisting in counting how many standards were contained in the test stimulus for shorter test stimuli and in counting how many times a standard about 10 cm long was contained in the test stimulus for longer test stimuli. One example of a variant of this strategy was counting how many standards were contained in half of the test stimulus multiplying the resulting count by 2.

General Discussion

The results show that the psychophysical function for frontal length obtained by magnitude estimation exhibited, depending on the participant, a rather abrupt increase or decrease in rate of increase at the length of about 10 cm. This change in rate of increase was also noted by Pitz (1965) who attributed it to number bias. Its occurrence was confirmed in this study by a decrease in all participants of the rate of increase of response time at the length of about 10 cm.

These results support the possibility that subjects simultaneously used two different standards to make magnitude estimations of line length. The length of one standard was close to the perceived length of the 0.94-cm standard for stimulus lengths up to about 10 cm, and the length of the other standard was close to the perceived length of a standard of about 8 cm for stimulus lengths longer than 10 cm.

Abrupt changes in direction of the psychophysical function (called “breaks”) similar to those reported here have been reported for magnitude estimation and production of perceived duration (Eisler, 1975; Richards, 1964). Parenthetically, the present results support the possibility that these “breaks” for magnitude estimation or production of perceived duration reflect the use of different mental standards of perceived duration rather than reflecting differences in perceived duration.

Magnitude estimation of frontal line length yields wide variation in individual exponents of the psychophysical power function (Teghtsoonian & Teghtsoonian, 1971). The present results show that differences in length of mental standards among subjects and/or their change with test stimuli determined this individual variation. For example, for Subject 2, $c = 0$ in Equation 1 for test stimuli in the range of 2–10 cm and $c > 0$ for test stimuli in the range of about 15–50 cm. Since c was larger for test stimuli in the range of 15–50 cm than in that of 2–10 cm, β turned out to be *larger than unity*. On the other hand, for Subject 15, $c > 0$ for test stimuli in the range of 2–10 cm and $c < 0$ for test stimuli in the range of 10–50 cm. Since c was smaller for test stimuli in the range of 15–50 cm than in that of 2–10 cm, β turned out to be *smaller than unity*.

Magnitude estimation of frontal line length yields a mean exponent of the psychophysical power function ranging typically from about 0.9 to 1.1 (Baird, 1970, pp. 42–43). The present results show that this unpredictable variation in mean exponent between experiments depends on the values of c ($c = 0$, $c < 0$, or $c > 0$) occurring in the subjects randomly selected for the experiments.

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