and within-group serial position curves are affected more by the number of items presented than by the number of items to be recalled, when the number of items presented and recalled is well beyond the memory span as it is in the experiments reported here. These findings suggest the general conclusion that the number of items presented is a more important determinant of short-term memory above the memory span than the number of items to be recalled.

The decrement in short-term recall produced by increasing the number of items presented and the relatively small improvement with practice suggests that human beings are not able to ignore an item that need not be remembered when it is embedded in a sequence of items that are to be remembered. Perhaps the item before the item that need not be remembered is automatically associated to the item that need not be remembered, and this unnecessary association competes with the necessary association between the two items surrounding the item that need not be remembered. Alternatively, subjects may not even attempt to learn 12 item sequences in *P*16-*R*12 and may rehearse and recall these sequences the same as ordinary 16 item sequences. In either case it appears that the human short-term memory system is unable to ignore the extra items.

The relatively small effect of increasing the number of items to be recalled from 12 to 16 contrasts sharply with Anderson's findings for increases from four to eight to twelve[3]. It appears that the number of items to be recalled is a much more important variable below or in the vicinity of the memory span than it is above the memory span. Subjective reports suggest that there are two stages in short-term recall: first, a rapid ordered recall output of those items of which one is surest and, then, a slower free recall output of those items which one thinks were probably in the sequence. The ordered recall mechanism is assumed to be more accurate than the free recall mechanism. If there are these two semi-independent mechanisms for short-term recall, then the findings concerning the importance of the number of items to be recalled suggest that the ordered recall mechanism is much more vulnerable to interference from the recall of prior items than is the free recall mechanism.

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[1] Pollack, I., *Amer. J. Psychol.*, **66**, 421 (1953).
[2] Pollack, I., Johnson, L. B., and Knaff, P. R., *J. Exp. Psychol.*, **57**, 137 (1959).
[3] Anderson, N. S., *J. Exp. Psychol.*, **60**, 216 (1960).

Neural Effects and the Psychophysical Law

THE claim that the true psychophysical law is a power function[1] instead of a logarithmic[2] law has led to a number of misunderstandings about the real significance of Stevens's point of view.

Treisman[3] has tried to show that the so-called 'stimulus function' conceived to be both a power function and a logarithmic one. His model involves the stimulus function as a relation between the stimulus-level and the level of central neural effects (C), the magnitude of which depends on the stimulus intensity, $C=f(I)$. To scale the sensory magnitude in a 'direct' ratio-scaling procedure the subject is asked to report whether a variable stimulus is greater or less than twice the standard. Such an instruction to the subject involves a criterion to be met by the sensory magnitudes, with the scaling procedure leading to fixed ratios between the adjusted and standard stimulus intensities.

On this basis, Treisman shows that two criteria for the central neural effects (C) may arise: that is, his formulæ (3) $C''/C' = d = 2$ and (5) $C'' - C' = j = \log 2$. Depending on the choice of the 'stimulus function' these criteria can be derived; the first criterion is brought about by a power function and the second one by a logarithmic relation.

At this point in his model, Treisman jumps from the subjective magnitudes to the values of the hypothetical central neural effects (C). Whether this is correct is questionable.

In other words the criteria can be described as follows. The hypothetic central neural effects (C) have to be adjusted until their values show up a ratio of a factor 2. The second criterion asks for central neural effects which show up a difference in magnitude by the amount of log 2. The first criterion seems rather sound in so far as the instruction is also expressed in terms of making the variable stimulus twice the standard. Thus, in using this criterion one may hope that the central neural effects (C) are related to sensory magnitudes in at least a proportional way. The second criterion, however, demands a constant absolute difference between the central neural effects to be in line with the instruction of doubling the sensory magnitude. Since the difference asked for amounts to log 2 in doubling the sensation, it seems as if the central neural effects (C) are logarithmically related to the sensory magnitudes. If so, then jumping from sensory magnitudes to the central neural effects is an unwarranted proposition.

The second criterion suggested by Treisman holds that the subject is able to compare central neural effects on an absolute scale and to derive conclusions from this comparison with respect to the magnitudes of the sensation. If true, the ratio scaling procedure leads to a proportional relation between the neural effect and the logarithm of the stimulus intensity. However, this result does not warrant the logarithmical character of the psychophysical function. The psychophysical law tries to relate sensory magnitude and stimulus intensity.

Thus, the relation between the neural effects and the sensory magnitudes should be taken into account. By the second criterion a proportionality between the neural effects (C) and the logarithm of the sensory magnitudes (S) is assumed, whereas the condition $j=\log 2$ requires an equality $C=\log S$. Insertion of this equality into the 'stimulus function' (formula (4)): $C=h \log I$ leads to a power function relating sensory magnitude and stimulus intensity.

In conclusion, the model suggested by Treisman is a valuable one towards solving the problems of matching abilities and ratio production in relation to neural events. His 'stimulus function' is a useful concept to operate with if one is interested in information processing in the nervous system. However, the 'stimulus function' cannot be taken as representative of the psychophysical relation between sensory magnitude and stimulus intensity.

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[1] Stevens, S. S., *Amer. Sci.*, **48**, 226 (1960).
[2] Fechner, G. T., *Elemente der Psychophysik* (Leipzig, 1860).
[3] Treisman, M., *Nature*, **198**, 914 (1963).

THE question of the proper empirical basis of the 'psychophysical law' has caused much controversy. It has been held that 'indirect' methods of scaling 'sensation', such as cumulating *j.n.d.*'s, lead to log functions, and 'direct' procedures to power functions, and argument has usually been directed to showing that one type of procedure is better than the other, and therefore that one function, but not the other, gives the 'correct' measure of