nearly of equivalent length (Fig. 3). Yet, these two ranges produced the two extreme group exponents.

Stimulus range is a major contributor to group differences and to individual changes in performance on a psychophysical scaling task. The present data indicated that Ss adjust their response ranges with changes in stimulus range. However, the critical measure of stimulus range affecting response range appears to be the number of discriminable steps contained in the stimulus range rather than the absolute physical range. These results point to boundary conditions for Poulton's (1968) Model I. There are situations in which Ss will decrease their range of numerical responses in the face of a fivefold increase in physical range. Variation in subjective range may not show up as a variation in the power law's exponent when discriminability is variable over different portions of the physical continuum.

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Reaction time and short-term visual memory*

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Posner's method of using differences in RT for physical and name matches to estimate the time constant of visual STM is criticized as confounding the decay of the visual trace with the development of a name code. When this confounding is avoided by using stimuli that are hard to name (a 5 by 5 matrix of randomly filled squares), the time constant shown by both RT and errors is consistently longer than that reported by Posner.

Posner and his co-workers have recently devised an ingenious technique by which reaction-time (RT) measures may be used to study visual encoding, and from which they have drawn interesting conclusions about short-term visual memory. The technique involves presenting S with a letter, followed after a brief interval by a second letter which may be either the same or a different letter and may be either upper- or lowercase. When the second letter immediately follows the first, RT is

faster if the two are physically identical (i.e., same letter, same case) than if the letters have the same name but are in a different case. As the interval between the two increases, this difference decreases, till it disappears at delays of 1.5 sec or longer (Posner & Keele, 1967; Posner, Boies, Eichelman, & Taylor, 1969). They interpret this as evidence for a short-term visual trace with a decay time of about 1.5 sec.

The existence of such a trace is of considerable interest, since its time constant is clearly longer than that of iconic storage (Neisser, 1967). On the other hand, this time constant is considerably shorter than that for visual STM suggested by Posner (1967). Blick

(1969), and Dale & Folarin (personal communication). Posner found little or no decay over a 20-sec interval; Blick found decay continuing beyond 5 sec; and Dale and Folarin found decay continuing beyond 10 sec. Closer examination of the rationale behind the Posner result, however, suggests that it may be based upon a logical error. It assumes that the discrepancy between the RT to physically identical terms and terms with the same name but different case simply reflects the strength of the physical trace, with the two RTs becoming equal when the trace becomes indistinguishable from the visual background noise. It is clear from Posner's own experiments, however, that at the same time as the physical trace is fading, the item is being translated into a name code. The point at which the difference between the physical and name match RT disappears, therefore, represents the combined effect of a fading visual trace and a developing name code. Once the name code has developed to a point at which it allows faster RTs than the visual code, S will presumably use it in preference to the visual trace, even though visual trace continues to be available. Since S need no longer use the visual trace, his RTs will no longer reflect its strength. In short, Posner's technique confounds the fading of the visual trace with the development of the name code, and as such cannot give a valid indication of the time course of visual STM.

This suggests that the method of Posner & Keele (1967) may give an underestimate of the duration of visual STM, and that the longer times suggested by the other experiments are more accurate. However, the discrepancy may be due to differences in procedure. All three experiments suggesting longer times measured accuracy rather than reaction time, and studied memory for position or length rather than memory for form. Furthermore, Posner (1967) and Dale and Folarin used recall rather than recognition. The following experiment, therefore, studies visual STM using a technique analogous to that employed by Posner and Keele, but material which cannot easily be named in order to avoid the confounding of visual trace decay with name-code development.

METHOD

Stimuli comprised a 5 by 5 matrix of squares in which each square had a 0.5 probability of being filled. A new pattern was used each trial. After a randomly selected delay of 0.3, 1.0, 3.0, or 9.0 sec, a second matrix was presented. This was either identical to the first or differed by having one square more or one square less filled. Ss were instructed to decide "as quickly as possible without error," whether

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Fig. 1. Percentage correct recognition responses as a function of delay (chance level = 50%).

the second pattern was the same or different, and press one of two display-console keys accordingly. The second pattern remained in view until the key was pressed. Stimuli were exposed for 0.5 sec on the visual display of an Elliot 4130 computer. The 5 by 5 matrix measured 0.6 x 0.6 in., and was viewed from a distance of about 12 in. In order to minimize iconic storage effects, a masking field comprising a 10 by 10 matrix of randomly filled squares was interpolated between the two 5 by 5 stimuli.

Ss were given 60 practice trials

comprising 15 trials at each of the four delays in random order. The actual test involved a further six such blocks of 60 trials. Seven Ss comprising undergraduates and research workers were tested individually.

RESULTS

Figure 1 shows the overall mean percentage of correct Rs as a function of delay. In contrast to the results of Posner et al, our data clearly suggest that forgetting continues after the first 3 sec. All Ss show overall forgetting and all show a drop in retention between 3 and 9 sec

Fig. 2. Mean reaction time for correct and incorrect responses as a function of delay.

($T = 0$, $N = 7$, $p < .02$ on the Wilcoxon test). Mean RT was plotted separately for correct and incorrect Rs and is shown in Fig. 2. All Ss show an overall tendency for RT to increase with delay ($T = 0$, $N = 7$, $p < .02$). The increase in RT between 3 and 9 sec is also significant ($T = 1$, $N = 7$, $p < .05$). The trend is closely parallel for both correct Rs and errors, which are associated with slower RTs in all Ss ($T = 0$, $N = 7$, $p < .02$).

DISCUSSION

These results are clearly at variance with the time constant for visual STM suggested by Posner et al and, as such, they reinforce the claim that the physical vs name-match technique does not provide a valid indicator of short-term visual memory. They suggest a rate of forgetting which is consistent with the experiments suggesting a longer duration, despite considerable differences in procedure between this and the previous studies. Both accuracy and RTs give mutually consistent results, which suggests that RT may indeed provide a useful indicator of short-term forgetting.

Posner, Boies, Eichelman, & Taylor (1969) suggest that the decay of visual STM may be reduced by appropriate rehearsal strategies. They provide evidence for this by studying a pure-list condition in which, as in the present experiment, a physical match is always required. RTs increased little over the 1-sec interval studied. They interpreted this as due to increased rehearsal of the visual aspect in the pure-list condition. In terms of this view, the results of the present experiment would suggest that rehearsal can maintain a visual STM for the kinds of patterns used beyond 3 sec, but not beyond 9 sec.

As Posner et al note, their experiments do not show whether the decay observed is a matter of reducing ease of accessibility, or a matter of complete loss of availability. By showing a large increase in errors, as well as in RT, the present experiment suggests that the decay observed involves a complete loss of availability.

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