Word recognition with masking¹

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At illuminances between .07 and 17 ft.-c., the word-recognition threshold was lower when a common word was preceded and followed by a homogenous field than by a noise pattern composed of a random array of bits of letters. Most of the difference is ascribed to the pattern's interference with post-stimulatory processes. This interference may explain why with masking the threshold reached a minimum at 90 msec. and then did not decrease further despite increasing illuminance, whereas without masking the threshold continued to decrease down to 7 msec., the shortest duration tested.

This study concerned the effect of a pre- and post-exposure visual noise pattern on the time needed to identify common English words at various illuminance levels. Because visual information is usually available to the perceptual system after termination of a light stimulus, especially a bright one, physical duration is seldom an accurate measure of "perceptual duration." The physical and perceptual durations may become more alike, however, when the stimulus word is followed by a visual noise pattern instead of by the usual homogeneous, unpatterned field. Sperling (1960) has shown that such a pattern reduces the information obtained from a brief visual display when it follows the display immediately or with a delay up to 500 msec. The noise pattern apparently terminates post-stimulatory processes thereby shortening the perceptual duration; an unpatterned field (provided it is not too bright) does not.

Method

Visual-duration thresholds for common five- and six-letter English words were measured by the ascending method of limits in a two-field tachistoscope. Exposure durations were increased from 6 msec. in progressively larger steps that corresponded approximately to equal distances on a scale of clarity. At each duration the S presented the word by pressing a lever that turned on the exposure-field lights after 500 msec. and that also advanced the duration one step. The exposure of the word was preceded and followed by either: (1) a blank white card with approximately the same illuminance as the exposure field; (2) a card with a black-and-white random pattern composed of parts of letters and with an overall illuminance about one-third that of the exposure field;² or (3) a homogeneous "grey" card with approximately the same illuminance as the overall illuminance of the pattern. Each field condition was tested in a separate experimental session. Measurements were made at five illuminances, .07 to 17 ft.-c., with the pattern, and at three illuminances, .07 to .50 ft.-c., with the homogeneous fields. At levels not far above .50 ft.-c., many Ss could identify a word

preceded and followed by homogeneous fields even when the exposure duration was 6 msec., the shortest available. Therefore measurements were taken, using the homogeneous fields only, on a second group of Ss with the duration instead of illuminance held constant. The duration was set at 7, 15, or 25 msec., and the illuminance increased in steps of 0.1 log units until the S identified the word. For both groups of Ss, thresholds were determined for 10 words under each combination of field and duration or of field and illuminance. Order of presentation of word sets, field condition, and illuminance (or duration) were counter-balanced as far as possible among the Ss.

Words were selected from those in the Thorndike-Lorge list (Thorndike & Lorge, 1944) that have a general frequency count of 100 or more per million. Each word was typed in black uppercase letters on a white homogeneous card. A five-letter word subtended a visual angle of about $1^{\circ}20'$, with each letter 15" wide and 11" high.

Two Sylvania 14-watt fluorescent bulbs (super deluxe cool-white), which have rapid decay times, provided the light for the pre-exposure field, and a second pair for the exposure field. Illuminance was varied by means of Wratten neutral density filters inserted at the eyepiece. The fixation point was a small red dot illuminated from behind and placed just below the position of the word.

Eleven male undergraduates with uncorrected normal vision served in the main experiment, in which the duration threshold was measured. Seven other undergraduates, four men and three women, served in the supplementary experiment, in which the illuminance threshold was measured. Ss were paid to serve in three 1-hr. sessions in the main experiment and in two 1-hr. sessions in the supplementary experiment. Each session began with 5 min. of adaptation to the very dim illumination in the experimental room, followed by threshold measurements with ten practice words. Ss were encouraged to guess at all times.

Results

Figure 1 presents the mean duration thresholds for the 11 Ss of the main experiment (circles) and the mean illuminance thresholds, which are on the abscissa, for the seven Ss of the supplementary experiment (triangles). Each circle is the mean of 110 threshold determinations, and each triangle is the mean of 70 determinations. Although the energy (duration times illuminance) thresholds were lower for the second group than for the main group, the difference was not significant at the one duration, 25 msec. with the grey

Fig. 1. Mean word-recognition thresholds under three different pre- and post-exposure field conditions. Circles refer to measurements with the exposure duration varied, triangles to measurements with the exposure illuminance varied.

field, that was the same for both groups. So the results for the two experiments are discussed together. With the patterned field, the threshold decreased with increasing illuminance to 90 msec. and then remained constant. With the two homogeneous fields, the thresholds decreased with increasing illuminance throughout the range of illuminance tested. An analysis of variance of the results in the main experiment showed that the main effects of illuminance and field were highly significant ($p < .001$). The interaction between field and illuminance was significant ($p < .005$); the slopes of the threshold curves differ for the homogeneous and patterned fields. The interaction between Ss and field was also significant ($p < .001$) and means that some Ss had larger threshold shifts as a function of field condition than others. The individual threshold curves of all eleven Ss, however, were essentially the same as the average ones in Fig. 1. An analysis of variance of the results in the supplementary experiment also showed significant main effects and some significant interactions.

While producing higher thresholds, the patterned field produced less relative variability. In the main experiment, intra-S variability declined significantly when the pattern was used. The mean coefficient of variation was 34 with the white field, 43 with the grey, and 23 with the pattern. The inter-S coefficients of variation also tended to decline under masking, but not significantly.

Discussion

The patterned field clearly raised the word-recognition threshold. This threshold shift cannot be attributed to reduced illuminance in the pre- and post-exposure fields since the homogeneous grey field had approximately the same overall illuminance as the pattern, but yet did not raise the thresholds. Indeed, at higher

illuminances the grey field lowered the threshold relative to that with the brighter white field. Of course, these data cannot tell us whether it was mainly the pattern in the pre-exposure field or in the post-exposure field that was causing the threshold shift. (A three-field tachistoscope was not available for independent variation of the pre- and post-exposure fields.) Sperling (1963), however, has compared letter recognition with the noise pattern presented only after exposure of the letters and with the noise pattern presented both before and after. He found that adding the pattern to the pre-exposure field delayed letter scanning 20 msec., but otherwise did not interfere with performance. If this delay is approximately independent of illuminance over the range tested in the present experiments, then only a small part, 20 msec., of the threshold shift measured with the pattern was caused by interference from the pre-exposure field. Most of the threshold shift was caused by the pattern in the post-exposure field. The results may then be interpreted, along the lines suggested by Sperling (1960, 1963) and Averbach and Coriell (1961), to mean that the noise pattern interferes with the information still available after termination of a brief visual stimulus. This post-stimulatory information is much less susceptible to interference from or "erasure" by an unpatterned homogeneous field than by a patterned field. The post-exposure pattern, by preventing the quasi-continuation of the physical stimulus as a kind of after-image, yields a physical duration threshold that probably corresponds closely to the effective perceptual duration. Since the duration threshold with masking decreased to 90 msec. and then stayed constant despite further increases of illuminance, the minimum perceptual duration required for the identification of a common

five- or six-letter word may be about 70 msec. (90 msec. minus 20 msec. delay). This assumption implies that the threshold without masking continued to decline below 70 msec. because the brief but intense and unimpeded stimuli triggered post-stimulatory processes that together with the stimulus duration added up to the required perceptual duration. (The present data are too few to warrant conjecture about why the masked and unmasked threshold curves diverged at about 180 msec. and not at 90 msec., as might be predicted.)

A perceptual duration of 70 msec. is not fortuitous. It agrees with Sperling's (1963) finding that letters are scanned at a rate of one letter per 10 to 15 msec. At this rate, 50 to 90 msec. would be required to scan all the letters in these five- and six-letter words. Of course, Ss would not always need to see all five or six letters to identify a common word, but missed letters combined with misperceived letters would often lead to a false response, thus somewhat offsetting the contextual advantage.

The threshold curves measured with the homogeneous fields are also interesting in themselves. Although time could be traded for intensity at recognition threshold, the relation does not follow Bloch's law (intensity times duration is not a constant) at illuminances above about 0.2 ft.-c; below 0.2 ft.-c there are not enough data points to determine how well Bloch's law applies. However, previous experiments (Scharf, Holohan, & Morningstar, 1962) have shown that the word-recognition threshold without masking obeys Bloch's law with a critical duration of almost 300 msec. at illuminances below about 0.2 ft.-c. Similar critical durations have been measured by Hunter and Sigler (1940) for the perception of six dots and by Kahneman and Norman (1964) for the discrimination of digits. In the present experiments, Bloch's law does not seem to apply above about 0.2 ft.-c, precisely at those illuminances where the perceptual and physical durations begin to diverge widely.

We should add that the thresholds with the grey field became lower than with the white field at the higher illuminances probably because the dimmer grey field

interfered less with post-stimulatory processes, an effect already noted in 1871 by Baxt (as reported by Sperling, 1963).

Once these measures have been extended to lower and higher illuminances with independent variation of the pre- and post-exposure fields, we would want to test their reproducibility with simpler stimuli such as geometric patterns and simpler tasks such as detection. The reason for the marked reduction in intra-subject variability under masking also remains to be clarified, although it may have been due to removal of the post-stimulatory storage process as a source of variability.

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Notes

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