the results of Hepp *et al.*[16] that insulin has no effect on this enzyme.

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Interaction Effects in Parafoveal Letter Recognition

WHEN a person reads, his eye movements consist of fixational pauses separated by quick jumps along the lines. What the eye picks up during a pause is largely unknown, as is the way in which the information from successive retinal images is integrated. Properties of the visual system, as well as the reader's knowledge of the language, must be relevant.

To investigate the dimensions of the functional visual field in reading, that is, the field from which information is picked up during a single fixational pause, I presented letters briefly to subjects and noted their responses. By choosing letters rather than words, I aimed at isolating a visual recognition factor from more highly structured language factors.

If a single letter is presented eccentric to the point of fixation, its recognizability decreases as eccentricity increases. If two or more letters are presented simultaneously and close together, lower recognition scores are obtained[1–3]. This implies an adverse interaction which makes the functional visual field dependent on the arrangement of letters in words. My experiments show that the interaction is quite substantial.

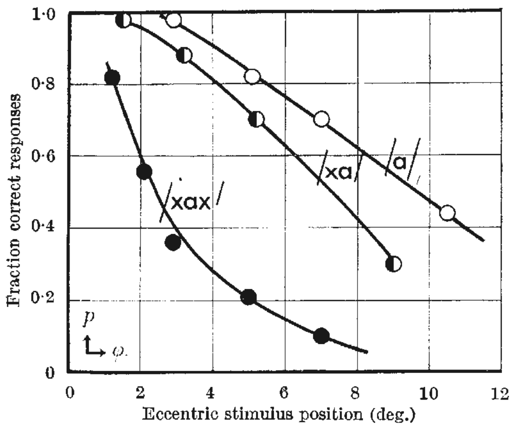

Fig. 1. Fraction of correct letter responses as a function of retinal eccentricity of the stimulus. Scores decrease substantially when the stimulus is flanked at normal spacing on one side (the foveal side) (/*xa*/) or at both sides (/*xax*/). Observer, H. B.

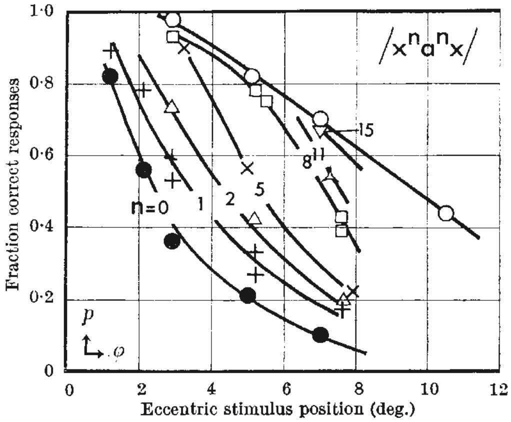

Fig. 2. Fraction of correct letter responses as a function of retinal eccentricity of the stimulus. Observer, H. B. The embedded stimulus letter has gradually been isolated visually by leaving n ($n=1, 2 \ldots 15$) spacings open between the stimulus and each of the two flanking /*x*/ letters. One spacing corresponds to 0·29° visual angle. For a stimulus at $\varphi°$ eccentricity, an open distance of roughly $0·5\ \varphi°$ is required for complete isolation.

In order to find the retinal distances over which the interaction operates, I gradually increased the distances between adjacent letters until recognition scores for embedded letters equalled the values for single letters.

The stimuli were twenty-five lower case letters of a type font with pronounced serifs (Courier 10). The height of the short letters is 1·95 mm, extensions 0·75 mm. Letter width is between 1·4 and 2·5 mm at a spacing of 2·55 mm. At the reading distance of 50 cm, 1 mm corresponds to a visual angle of 7 minutes of arc.

The letters were typed with an IBM "pingpong ball" typewriter through carbon-tape on a long sheet of white paper. In a two-channel tachistoscope, a blank field (60 cd/m^2) was replaced for 200 ms by an equally bright field in which one of the typed lines was present. A fixation mark was continuously visible. 200 ms is in the lower range of normal fixational pause lengths. I have checked that correct fixation was maintained during the exposure. The observer used binocular vision with uncontrolled pupils (diameter about 5 mm).

The observer started the presentation by releasing a pushbutton when looking at the fixation mark. He reported either a letter (in a spelling alphabet) or "illegible". The experimenter wrote down the response and shifted the sheet towards the next line. Only one type of flanking was used in each session.

In the figures, each point shows the fraction of correct responses of at least 100 presentations: each of the letters four times in random order, randomly right and left of the fixation mark. Left and right scores were equal. A few monocular experiments gave slightly lower scores. The findings were checked with two other observers, who produced similar results.

Fig. 1 compares correct scores as a function of retinal eccentricity φ for single letters, letters flanked at one side (the inside) by a letter /*x*/ at normal spacing, and letters flanked at both sides by an /*x*/. If we indicate the letter to be recognized as /*a*/, we can use the symbols /*a*/, /*xa*/ and /*xax*/ respectively.

For letters presented singly, the scores show the usual decrease as eccentricity increases, ascribed to the decreasing visual acuity[4]. For embedded letters /*xax*/ a much steeper decrease obtains, reducing the diameter of the functional visual field by a factor of four. This value exceeds by far any acuity expectations. In 1898, Erdmann and Dodge[5] had reported that only four letters can be seen simultaneously in sharp vision.

For reading, my data imply that initial and final letters of words can be recognized individually at a greater distance from the point of fixation than can embedded letters. On this evidence alone it is impossible to decide whether readers indeed make a more extensive use of initial and final letters.

My experiments are distinguished from experiments in which the number of letters to be reported exceeds the observer's memory span. Higher scores for initial and final letters are also found in these short term memory experiments, but recognition of embedded letters remains possible[6] and retinal eccentricity is of little importance[7].

Next, for the /*xax*/ situation, I increased the distances between the unknown letter and the two flanking /*x*/ letters by leaving 1, 2, 3 . . . 15 spacings open. The gradual isolation of the unknown letter brings the scores back to those of single letters, as expected, but the required distances turn out to be far greater than I had anticipated. For complete visual isolation of a letter presented at an eccentricity of $\varphi°$, it follows that no other letters should be present within (roughly) $0{\cdot}5\ \varphi°$ distance. Similar values were obtained for two other observers.

A pilot experiment indicated that, in the /*xa*/ situation, the adverse interaction is stronger if the interfering /*x*/ is at the peripheral side of the unknown letter rather than the foveal side. The area of interaction is thus not quite circular around the position of the unknown letter but, rather, egg-shaped towards the retinal periphery (compare ref. 3).

Although letters are easy configurations for the demonstration of this form of interaction, its nature and specificity can be better investigated with less complicated stimuli. As well as being relevant to reading (and consequently to the layout of print) it is likely to take part in visual processes other than form perception, such as those determining visual conspicuity, and in visual search.

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Passing the Strongly Voiced Components of Noisy Speech

Running speech can be processed electronically so as to leave only the strongly voiced speech sounds, with silent gaps at other points in the speech continuum. This "gating" is achieved by detecting energy in a bandwidth corresponding to the presence of strongly voiced speech sounds; that is, 400–800 Hz. The detector controls an amplitude-limiter which blocks all weakly voiced components while passing the strongly voiced components with an effectively unlimited bandwidth. Such gated speech sounds stultified and is markedly less intelligible than the original. Cherry and Wiley have demonstrated, however, that the addition of white noise in the silent gaps of the gated speech can increase its intelligibility[1,2], and evidence has been adduced that this is because of a restoration of a rhythmic pattern in the speech.

In the experiments by Cherry and Wiley a preferred level of added noise was derived subjectively by each listener and used for all listening tests. Sizable individual differences were noted in the selected intensity of added noise. I have presented gated sentences (five to eight words in length) either without noise added in the gaps between strongly voiced components (the control condition), or with one of four levels of added noise. The five conditions were presented in random order to each of nineteen observers. The results (Table 1) indicate that the lowest intensity of added noise gave the highest intelligibility ($P < 0{\cdot}01$). In general, the higher the level of added noise, the poorer the performance became. There was little individual variation in the effect of different levels of added noise (coefficient of concordance $= 0{\cdot}85$, $P < 0{\cdot}01$) and eighteen of the nineteen subjects produced the highest score with the lowest level of added noise. The results contrast with those of Wiley[1] and suggest that individual variations in his experiments reflect preference behaviour only and are largely unrelated to overt performance.

Table 1. INTELLIGIBILITY OF PROCESSED SPEECH WITH DIFFERENT INTENSITIES OF ADDED WHITE NOISE

	Added noise level (relative to peak speech amplitude)				
	4 dB	0 dB	−4 dB	−8 dB	Control
Intelligibility	18·7	26·1	39·7	50·3	33·7

Intelligibility scores represent the percentage of words reported correctly. Words with changed endings (for example, leader—leading, lead—leads) were scored as correct. The definite and indefinite article was not scored.

The utility of low level added noise in enhancing intelligibility reinforces the idea that the added noise serves to restore the rhythmic continuity of speech. With no added noise speech is stultified, but with too much added noise there is insufficient intensity contrast between the voiced and non-voiced components.

The lack of intensity contrast between voiced and non-voiced components, and consequent loss of the accurate time pattern between speech components, might be one factor affecting the intelligibility of normal speech in high levels of masking noise. If so, it should be possible using the gating procedure I describe to replace the noise-only episodes in a noisy speech continuum with some lower level of added noise. If this procedure accentuates the rhythmic pattern of the original speech it is possible that gated noisy speech with some low level of noise added in the gaps might be more intelligible than the ungated noisy speech. By attempting to enhance the timing pattern through the gating procedure, there is an inevitable loss of the weakly voiced components, but if these components are relatively less useful cues in the presence of loud masking noise, it may nevertheless be possible to produce a net gain in intelligibility in comparison with ungated noisy speech.

Sentences were recorded in white noise to give a peak syllable-to-noise ratio of approximately 0 db, and approximate intelligibility value of 70 per cent. These noisy sentences were then put through the gating device, which was set to detect energy in the 400–800 Hz bandwidth. The gating device cannot discriminate perfectly between noise alone and noise plus strongly voiced speech components because the intensity difference between these two conditions is small, but the sensitivity of the gating device can be adjusted. For severe gating, the sensitivity is adjusted to exclude all the noise-only episodes in the original noisy message, but because of this only the highest energy voiced components are passed. For moderate gating, approximately 40 per cent of the white noise from the noise-only episodes is passed (called intrusive noise), and a substantially greater proportion of the voiced components of the speech is passed than in the severe gating conditions. These two sensitivity settings were used in the present experiment, together with a condition in which no gating was employed. Four levels of noise were added to the gaps in the gated speech, that is, at periods when neither speech plus noise, nor intrusive noise, was present; a no-noise condition was also included. All conditions were presented in random order in blocks of fifteen sentences.