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SACCADIC SUPPRESSION AND ADAPTATION

Revisiting the Methodology

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1. INTRODUCTION

The likelihood of perceiving the displacement of an object which occurs during a saccade is much lower than the likelihood of detecting such a movement during fixation ("saccadic suppression of image displacement", or SSD). The methodology of inducing such unseen intrasaccadic target movements has been used to study adaptive changes in saccadic amplitude (first by McLaughlin (1967), and subsequently by many others including Mack, Fendrich, and Pleune (1978), Erkelens and Hulleman (1993), and Deubel (1995)). SSD was first quantitatively described in an experiment where the entire visual field was displaced (Bridgeman, Hendry, and Stark, 1975). Later studies have often used the displacement of small targets. We suggest that the induction of saccadic suppression with small targets requires more stringent conditions than those established by Bridgeman et al. for movement of the entire visual field.

2. METHOD

In a signal detection study, eye movements of 21 normal subjects (including 3 non-naive (the authors); mean age 24 years; 13 male) were recorded using a Skalar IRIS infrared limbus tracker. A computer-generated stimulus (a red square target subtending 0.75º on a homogeneous background) was video front-projected on to a large screen. Subjects were instructed to follow the target as it jumped horizontally by 8, 12, 16, 20 or 24º.

During the saccade toward the new target position, the target was displaced centripetally by 1, 2, 3 or 4º in 120 trials (thus displacement ratios ranged from 0.04 to 0.50).

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An average of 27 ms was required from saccade initiation until the target could be di placed. (This comprised a mean 15 ms to reach and detect the $30°s^{-1}$ velocity threshold in dicating saccade initiation, a further 5 ms to move the target, and a mean delay of 7 m due to screen refresh rates.) As the average saccade duration was 68 ms, this was we within the SSD "critical period". Added to this were set delays of 0, 10, 20, 35, 50, or 6 ms to assess differences in detection between targets displaced intrasaccadically and thos displaced after the eyes had come to rest.

On 60 "catch" trials, the target was not displaced during the saccade. Subjects re ported awareness of intrasaccadic target displacements by pressing a key.

3. RESULTS AND DISCUSSION

We found that the SSD effect required larger saccade sizes, and smaller intrasaccadic displacements, than is commonly accepted. The conventional rule-of-thumb is tha the displacement ratio (the ratio of the intrasaccadic shift to the saccade size) should be n more than one third (Bridgeman et al., 1975). Our results show that for displacements of small target, a displacement ratio of 0.3 produces minimal suppression (see Figure 1), and we suggest that the ratio used be a value closer to 0.1, in order to ensure that subjects ar not consciously aware of the majority of target displacements. Other researchers (e.g. I and Matin, 1997; McConkie and Currie, 1996; Mack, 1970) have also advocated the us of a displacement ratio of 0.1 when employing such stimuli. Part of the difficulty in agreeing on consistent stimulus parameters is the lack of a definition of what would constitute an appropriate threshold level. The standard psychophysical threshold is arbitrarily set at the 50% detection rate. However, this level is too high for the purposes of studying adaptation to a target manipulation which one wishes the subject to be unaware of (particularly as the false alarm rate in SSD experiments is typically very low). Thus, researchers di placing small targets (with a displacement ratio of ≅ 0.3) in order to produce adaptation of saccades should be wary. They are possibly examining a conscious strategy rather than an unconscious perceptual learning process. (See Deubel's (1995) comments on Erkelens and Hulleman, 1993.)

Studies of saccadic parametric adaptation should include a signal detection pilot study in order to assess the effectiveness of their intrasaccadic displacement procedure But even those studies concerned with signal detection *per se* have tended to use a small number of (often non-naive) subjects. In any signal detection task, there exist wide individual differences, perhaps reflecting different response criteria rather than underlying dif

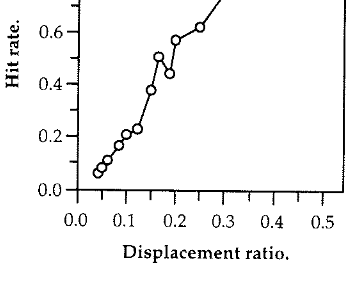

Figure 1. Probability of detecting an intra-saccadic target shift as function of the ratio of the size of that shift to the size of the saccad made to the target (the "displacement ratio").

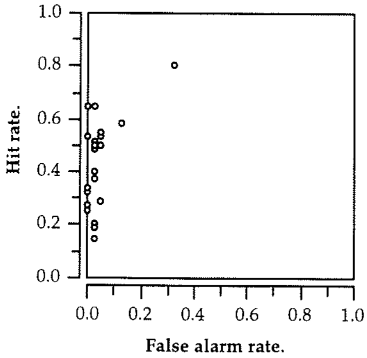

Figure 2. Hit rate vs False alarm rate for detecting intrasaccadic displacements. Each point represents one of 21 subjects, and scores are collapsed across all displacement ratios.

ferences in sensitivity to the stimulus. (That is, some subjects are more liberal or conservative responders than are others.) A lack of knowledge of individual differences in sensitivity and response bias must affect the conclusions one can draw from subjects' reports. This is especially so when only a small number of subjects are employed.

A comparatively large (n=21) number of subjects allowed us to gain an appreciation of individual differences. A subject who is a very liberal responder will have an inflated Hit rate (an indicator of sensitivity), but will consequently also have a higher False Alarm rate (an indicator of response bias). The scattergram (Figure 2) shows that subjects differed primarily in sensitivity rather than in response bias: only two of the 21 subjects had high false alarm rates. Thus it is encouraging that subjects appear to apply much the same response criterion when reporting awareness of intrasaccadic displacements; however there *are* marked individual differences in the sensitivity to those displacements (see also Wallach and Lewis, 1965).

The simultaneous collection of subjective event reports (i.e. keypresses indicating awareness of target displacement) and objective measures (i.e. eye movement recordings) provides a unique opportunity to validate the signal detection methodology (for example, the saccadic system may produce corrective eye movements in response to a target displacement which the subject may or may not be consciously aware of). Subjective reports and manual pointing have already been used to show that different information is available to the motor system and to the conscious level of the perceptual system (Bridgeman et al., 1979). Eye movements are a more direct and precise motor measure than manual pointing, and analysis of data from this perspective continues.

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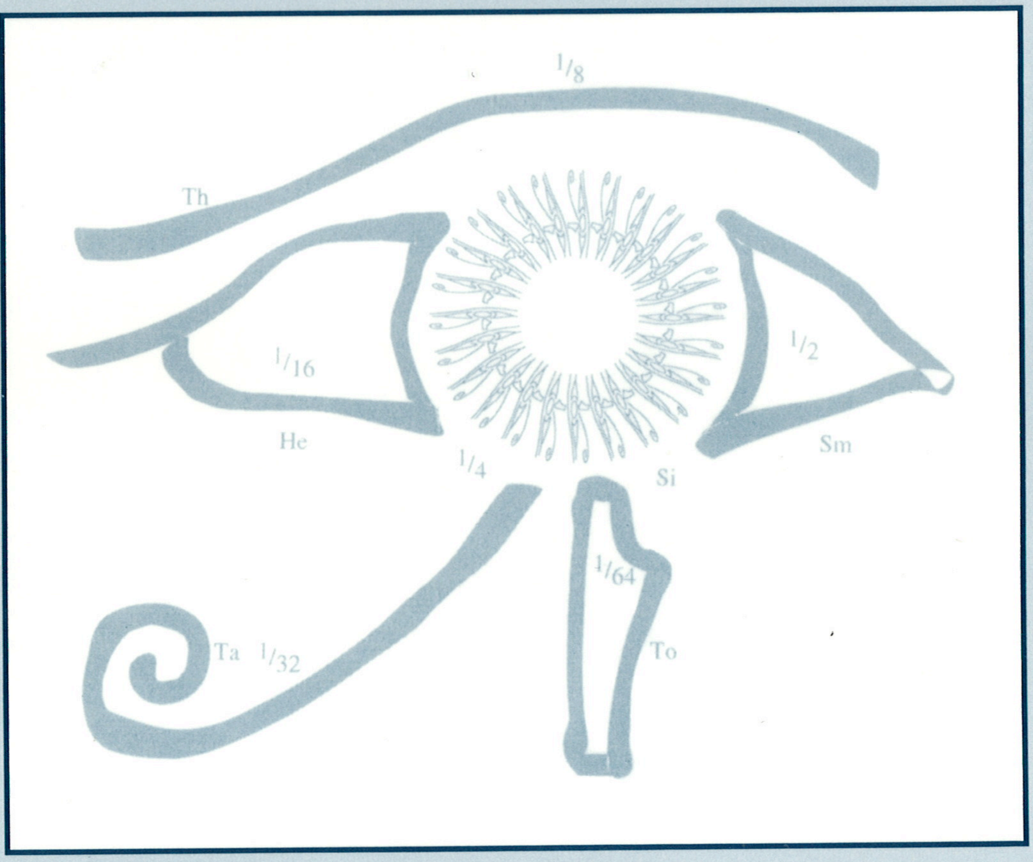

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