Vision Research 49 (2009) 1894–1900

Contents lists available at ScienceDirect

Vision Research

journal homepage: www.elsevier.com/locate/visres

The influence of fixation points on contrast detection and discrimination of patches of grating: Masking and facilitation

Robert J. Summers, Tim S. Meese *

School of Life and Health Sciences, Aston University, Birmingham B47ET, UK

A R T I C L E I N F O

Article history:
Received 21 August 2008
Received in revised form 18 March 2009

Keywords:
Human vision
Psychophysics
Masking
Fixation point
Contrast sensitivity
Methods
Psychometric function
Slope

A B S T R A C T

The use of fixation points (FPs) in visual psychophysics is common practice, though the costs and benefits of different fixation regimens have not been compared. Here we investigate the influence of several different types of FP configurations on the contrast detection of patches of sine-wave gratings. We find that for small targets ($\leqslant 1°$), the addition of a superimposed central FP can increase thresholds by a factor of ~1.3 (~2.5 dB) in comparison with no FP, and a factor of ~1.5 (~3.6 dB) in comparison with FPs that surround the target. These results are consistent with (i) a suppressive influence on the central region of the target from a central FP, and (ii) facilitatory influences from surrounding FPs. Our analysis of the slope of the psychometric function suggests that the facilitatory influence is not due to reduction of uncertainty. Plausible candidate causes for the facilitation are: (i) sensory interactions, (ii) aids to ocular accommodation and convergence, (iii) a reduction in eye-movements and (iv) more accurate placement of the observer's window of attention. Masking by a central FP is not found for the suprathreshold task of contrast discrimination, suggesting that the masking effects of pedestal and FP do not combine linearly. This means that estimates of the level of masking produced by a contrast pedestal can depend on the details of the fixation point.

1. Introduction

Fixation points, marks or contours (hereafter, FPs) are small visual indicators that are displayed either throughout, or extinguished just before, the presentation of a target. In contrast detection (and other types of psychophysical experiment) they are used because they are thought to help (i) achieve ocular accommodation (e.g. Owens & Leibowitz, 1975), (ii) achieve convergence (e.g. Marefat, Wu, & Yang, 1997), (iii) reduce eye-movements (e.g Legge & Campbell, 1981; see also Sheedy, 1981), and (iv) reduce spatial uncertainty (e.g. Legge & Campbell, 1981; Petrov, Verghese, & McKee, 2006). As each of these factors is likely to improve sensitivity, there is a general belief that it is good psychophysical practice to use FPs because this will improve the likelihood of measuring the observer's true sensitivity. However, although fixation itself has been studied intensively (see Coubard & Kapoula, 2005 for a brief review), surprisingly little research has been done to investigate whether FPs are effective or whether they have unwanted side-effects.

Of the studies that we know that have considered the roles of FPs in helping accommodation (Owens & Leibowitz, 1975) or reducing eye movements (Legge & Campbell, 1981), evidence is either weak or absent for their effectiveness, though circular FPs that surround the target (a ring) have been shown to improve mean fixation accuracy (Steinman, 1965). On the other hand, there are grounds for supposing a beneficial role for FPs by comparison with masking studies. For pedestal- or surround-masking experiments, it is claimed that the pedestal (Pelli, 1985) or annular mask (Petrov et al., 2006) reduces uncertainty and thereby improves performance. This is either by lifting the target above the level of the distracting noisy mechanisms (in the pedestal case) or by providing a cue to direct (spatio-temporal) attention in the annular or cross-oriented cases. Indeed, pedestals (Legge & Foley, 1980; Nachmias & Sansbury, 1974), annular masks (Meese, Summers, Holmes, & Wallis, 2007; Petrov et al., 2006; Yu, Klein, & Levi, 2002) and superimposed cross-oriented masks (Meese & Holmes, 2007; Meese, Summers, et al., 2007) have all been found to facilitate detection of the target (see also Meese, Holmes, & Challinor, 2007). However, it remains unclear how this facilitation should be apportioned between reduction of uncertainty (Pelli, 1985), sensory interactions (Chen & Tyler, 2001; Meese, Summers, et al., 2007) and direct excitation of the target mechanism by the mask (Legge & Foley, 1980; Stromeyer & Klein, 1974). Nevertheless, it seems plausible that FPs might cause effects that are similar to at least some of these types of facilitatory mask (Meese, Summers, et al., 2007; Petrov et al., 2006).

In general then, there are reasons to suppose that FPs will help the observer detect the target. However, a recent study highlighted

* Corresponding author.
E-mail address: t.s.meese@aston.ac.uk (T.S. Meese).

0042-6989/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.visres.2009.04.027

the possibility of adverse effects of FPs (Meese & Hess, 2007). For small patches of target grating (∼0.4°), contrast detection thresholds were about 1.76 dB (a factor of 1.2) lower when using four FPs arranged in a square around the target ('quad' FPs – see ahead to Fig. 1B) than when using a single point placed in the centre of the display ('central' FP – see ahead to Fig. 1A). However, it was not clear whether the differences arose from masking by the central FP or extra facilitation from the quad of FPs. As suppressive interactions between masks and targets are well established (Foley, 1994; Meese & Holmes, 2002, 2007; Ross & Speed, 1991) the possibility of suppressive influences from FPs is a distinct possibility.

There were two main aims to the present study. First, to conduct a detailed investigation of the effects of FPs on contrast detection thresholds. We did this for several configurations of FP and for several sizes and spatial frequencies of grating-type targets. Second, to try and establish whether the differences found by Meese and Hess (2007) were due to masking from the central FP or facilitation from the quad of FPs. We achieved this second goal by introducing a new form of FP configuration: a quad of FPs with an additional central FP. Comparisons between this and the other configurations were intended to reveal the influence of the two different components to the configuration. We conclude that both processes occur: central FPs can have a marked suppressive effect (>3 dB of masking) when the target is small, and surround FPs can improve detection (∼1.5 dB) beyond that found without FPs.

These results were first presented in abstract form by Summers and Meese (2007).

2. Methods

2.1. Equipment

Stimuli were displayed on an Eizo M9000 CRT with a frame rate of 120 Hz using a CRS VSG 2/5 stimulus generator operating in pseudo 15-bit mode. The mean luminance of the central region (512 × 512 pixels; 5.4° × 5.4° of the display was 40 cd/m^2. The surrounding region of the display was dark (<1 cd/m^2). Gamma correction was performed to ensure linearity over the full range of target contrasts. Observers sat in a dark room at a viewing distance of 220 cm with their head in a chin and headrest. The casing of the display monitor was clearly visible to the observers. The experiment was controlled by a PC.

2.2. Stimuli

Except where stated, stimuli were 3 cycles of a horizontal sinusoidal luminance grating modulated by a circular raised cosine envelope with a central plateau of one cycle and a blurred boundary width of one cycle (i.e. a full-width half-height of 2 cycles). Stimulus duration was 100 ms.

In Experiment 1, four stimuli were used with spatial frequencies of 1, 2, 4 and 8 c/deg, subtending 3°, 1.5°, 0.75° and 0.375°, respectively. Most of the subsequent experiments were carried out with the 4 c/deg grating patch, though Experiment 3 used the 1 c/deg patch. In Experiment 4 the full diameter of the 4 c/deg patch was extended to 12 cycles, matching the size of the 1 c/deg grating in Experiment 1. The spatial envelope was also the same as that used for the 1 c/deg patch (i.e. the central plateau was 4 cycles in diameter and the full-width at half-height was 8 cycles). Stimuli were always presented in the centre of the display and were in sine-phase (as shown in Fig. 1) and were viewed binocularly.

Contrast is expressed as Michelson contrast (C) in % ($C = 100(L_{max} - L_{min})/(L_{max} + L_{min})$) and in dB re 1% ($20 \cdot \log_{10}(C)$).

2.3. Fixation points (FPs)

In Experiment 1 four different arrangements of FPs were used: no FP, a central FP (Fig. 1A), a quad of FPs (Fig. 1B) and a quad of FPs plus a central FP (Fig. 1C). The size of each FP was 2.6′ square (4 × 4 pixels square) and was of the lowest luminance available from the monitor, appearing black. The centre of each point in the quad FPs lay on the corners of a square that surrounded the target. The side of the square was equal to the full width of the stimulus plus two pixels (1.3′).

In further experiments, other arrangements of FPs were used and are described in Section 3.

2.4. Procedure

In most experiments, the contrast level of the target was selected by a three-down, one-up staircase procedure (Wetherill & Levitt, 1965) and the threshold for a single FP was tested using a pair of randomly interleaved staircases (Cornsweet, 1962). The test contrast always began well above detection threshold and in an initial stage of data collection a large step-size was used (12 dB). After the first reversal the step-size was reduced to 3 dB and data collection continued for a further 12 reversals of each staircase. These last 12 reversals constituted the test-stage for each staircase. In Experiment 5 we used a method of constant stimuli (MCS) with 3 dB spacing between each of six target contrast levels. A single experimental session involved 20 trials randomly interleaved from each of the six target contrasts (i.e. 120 trials for each FP condition). In this experiment targets were presented on a pedestal contrast of either 0% or 20%.

We used a two-interval forced-choice (2IFC) procedure, where one interval contained the target and the other interval was blank. The onset of each 100 ms test interval was indicated by an auditory tone and the duration between the two intervals was 400 ms. Observers were required to select the interval containing the target using one of two buttons to indicate their response. Correctness of response was provided by auditory feedback, and the computer se-

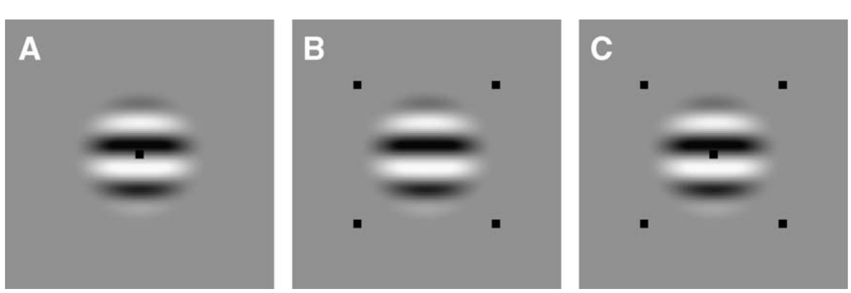

Fig. 1. Examples of the fixation points (FPs) used in the experiments with a 4 c/deg patch of target grating. The target has a full-width at half height of 2 cycles (0.5°). (A) Central FP. (B) quad FP. (C) quad + central FP. In each panel, the FPs are shown in true scale against the size of the target patch.