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The Effect of Stimulus Parameters (Size, Complexity, Depth and Line Thickness) on Horizontal Fusional Amplitudes in Normal Humans

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ABSTRACT: Stimulus size, complexity (detail), depth and line thickness were varied to determine their effects upon horizontal fusional amplitudes.

Subjects viewed flat fusion stimuli of varying size and detail, and a large disparity random dot stereogram (660 arc sec RDS). During testing, maximum fusional amplitudes and recovery values were recorded.

It was found that as stimulus size increased, fusional amplitude increased. Neither retinal disparity as presented in a RDS, or stimulus complexity/detail, however, influenced performance. When single lined flat fusion targets were varied in width (thickness), fusional amplitudes were unaffected.

These findings suggest that the dominant factor in fusion is not the amount of detail or the total area of direct retinal stimulation, but rather the amount of retinal area contained within the boundary edges of the stimulus.

Consequent clinical recommendations include the use of large targets at the initiation of binocular vision (fusion) therapy, with systematic progression to smaller targets. Use of targets of varying complexity, detail, and retinal disparity (depth) may not have an advantage over other simple fusion targets in orthoptic therapy.

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INTRODUCTION

Measurement and improvement of fusional amplitudes in patients with binocular anomalies is clinically important (1-4). Fusional amplitude measurements have been shown to vary with the method of stimulus presentation, the size of the stimuli, and the complexity of the stimuli (1-4). Most experimental studies have demonstrated that stimulus size and complexity affect both vertical and cyclovergence amplitudes (5-8).

Bowman and Kertesz (8) have studied the effect of stimulus size, complexity, and stereoscopic disparity on horizontal fusional amplitudes and recovery values. Though they report that their experimental results demonstrate that the diplopia threshold and refusion point are a function of stimulus size and complexity, their data do not support this conclusion. Certain small targets, i.e., a 1° x 1° cross and a 1° x 40° cross, yielded the smallest fusional amplitudes in two of four subjects, while these same subjects had similar fusional amplitudes with larger targets. When six other stimuli which varied in size were used, there was no difference in fusional amplitude or recovery. An earlier study, however, using 5°, 10°, 30°, and 50° circular targets with horizontal lines, did show that horizontal convergence and divergence fusional amplitudes increased with stimulus size (4).

One problem with the studies cited above was that stimulus size and complexity (detail) became confounding variables by not being varied *independently*.

The purpose of the present experiment was to remedy this problem and to systematically evaluate the effect of stimulus size and stimulus complexity/detail on maximum horizontal fusional amplitudes during convergence and divergence.

SUBJECTS AND METHODS

Ten subjects (5 male and 5 female) 20 to 30 years of age were selected and tested. All were paid volunteers. All subjects also signed an experiment participation consent form describing the nature of the study.

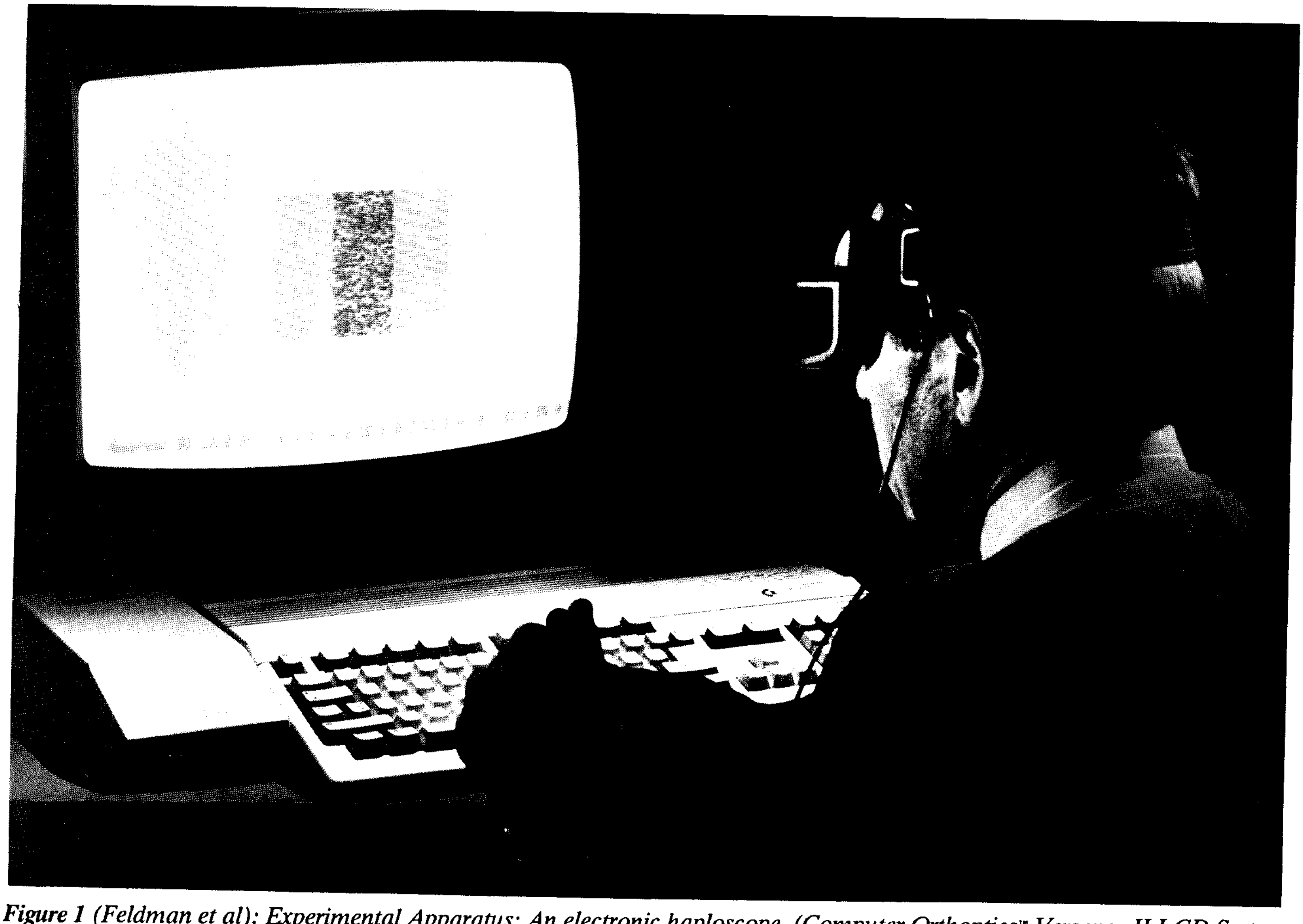

***Figure 1** (Feldman et al): Experimental Apparatus: An electronic haploscope. (Computer Orthoptics™ Vergence II LCD System, RC Instruments, Cicero, Indiana) The subject is wearing liquid crystal glasses. The glasses are connected to a dedicated Amiga 2000 HD computer system with interaction hardware and software. The subject views the monitor which presents the dichoptic stimuli (See Figure 2). Various stimulus parameters, as well as the subject's responses, can be manipulated or measured by either joystick or keyboard input.*

All wore their normal optical refractive error "correction" (i.e., spectacles or contract lenses) throughout testing. All subjects demonstrated a Snellen visual acuity (VA) of 20/25 or better with best "correction", astigmatism of 0.5 diopter (D) or less, a refractive error < +3/-3 D, no strabismus, no phoria >3 prism diopters (PD), or any ocular pathology. Each subject also had to correctly identify a 660 seconds of arc crossed disparity random dot stereogram (RDS) presented by a Computer Orthopter™ (See Figure 1, left, on facing page). All fusion stimuli were presented on this electronic haploscopic device - the Computer Orthoptics™ Vergence II liquid crystal system (RC Instruments, Cicero Indiana). The system presented computer-generated visual stimuli displayed on a 65 cm video monitor. The right and left eye images were alternately presented at 60 Hz. The images were electronically matched to the liquid crystal display glasses in which the right and left lenses alternately darkened completely. There was no cross-talk or ghosting evident. This resulted in dichoptically-presented stimuli (see Figure 2 directly below).

The computer-generated right and left eye targets were moved horizontally in opposite directions to create either a divergence or convergence demand of 1 PD/sec. The subject was required to maintain fusion for as long as possible and report when fusion was broken. As soon as diplopia occurred (the break point), the fusional amplitude was recorded. Then the vergence demand was gradually reduced until the subject reported refusion, which was noted as the recovery. Divergence testing always preceded convergence testing in order to reduce vergence adaptation.

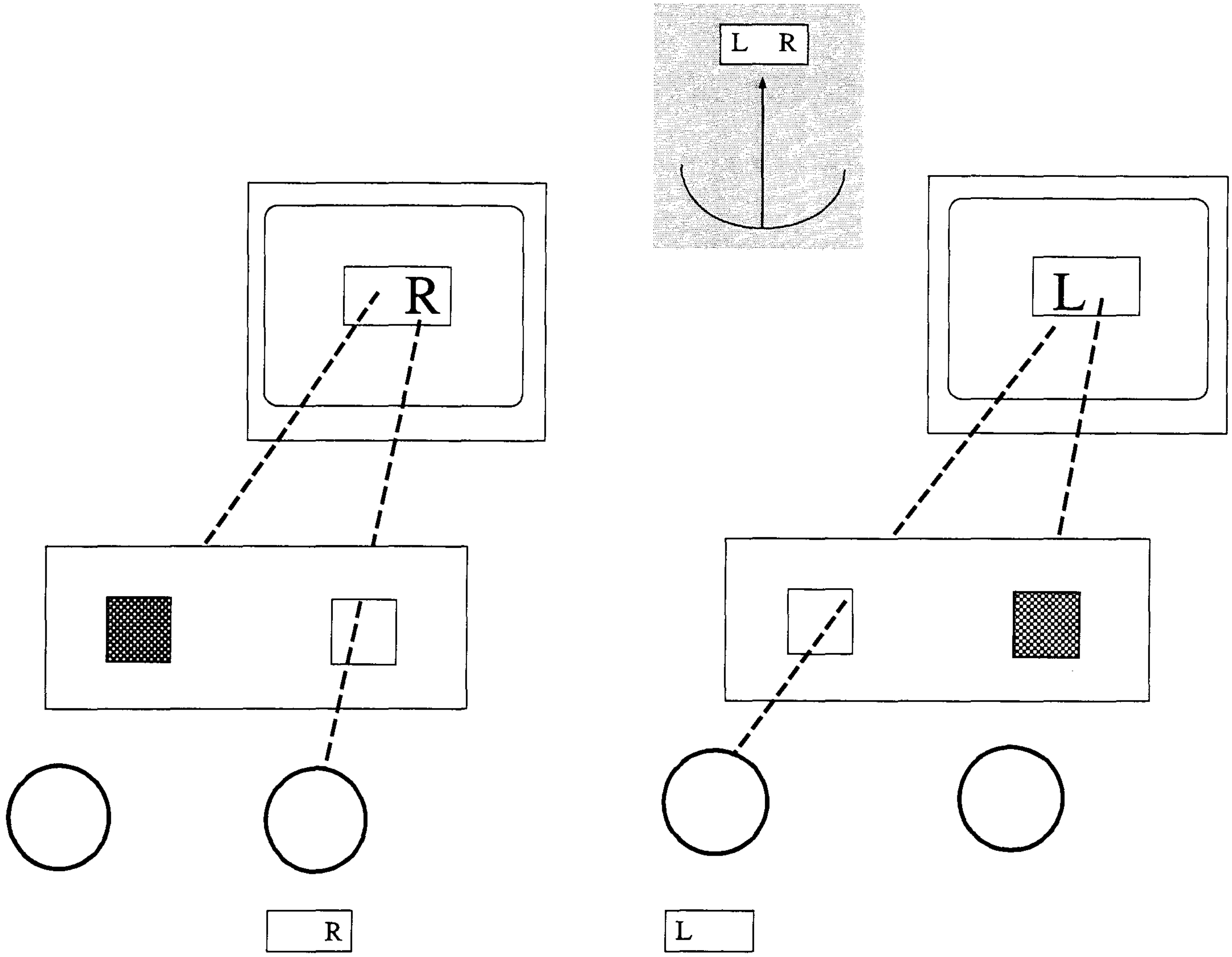

Figure 2 (Feldman et al): Experimental Apparatus: Schematic diagram of liquid crystal display haploscopic glasses system for separating images to eyes. Note that L and R images are alternately presented by the video monitor in sync with the alternately darkened left and right eye views of liquid crystal glasses.

The flat fusion **size stimuli** were represented by four simple unfilled and dot-filled squares having the following visual angles: 1.1°, 2.4°, 5.3°, 11.1° (see Figure 3, below). The width of the lines remained constant at 0.11°.

The **complexity and depth stimuli** were arbitrarily defined and identified as five qualitatively different square targets, each subtending the same visual angle of 11.1°. Four were flat fusion targets: an unfilled square; a square filled with a random dot pattern; a square with double the random dot size; and, a computer generated picture of a butterfly. The fifth square was a random dot stereogram (RDS) containing a small inner stereoscopic central square of 660 seconds of arc. This square was presented in crossed disparity (see Figure 4, right, next page).

A third set of stimuli varied **line width or thickness**, (but not length) of a vertical line target. There were seven line width stimuli: 0.11°, 0.22°, 0.44°, 0.55°, 0.77°, 0.99°, 1.11° (see Figure 5, overleaf >>>).

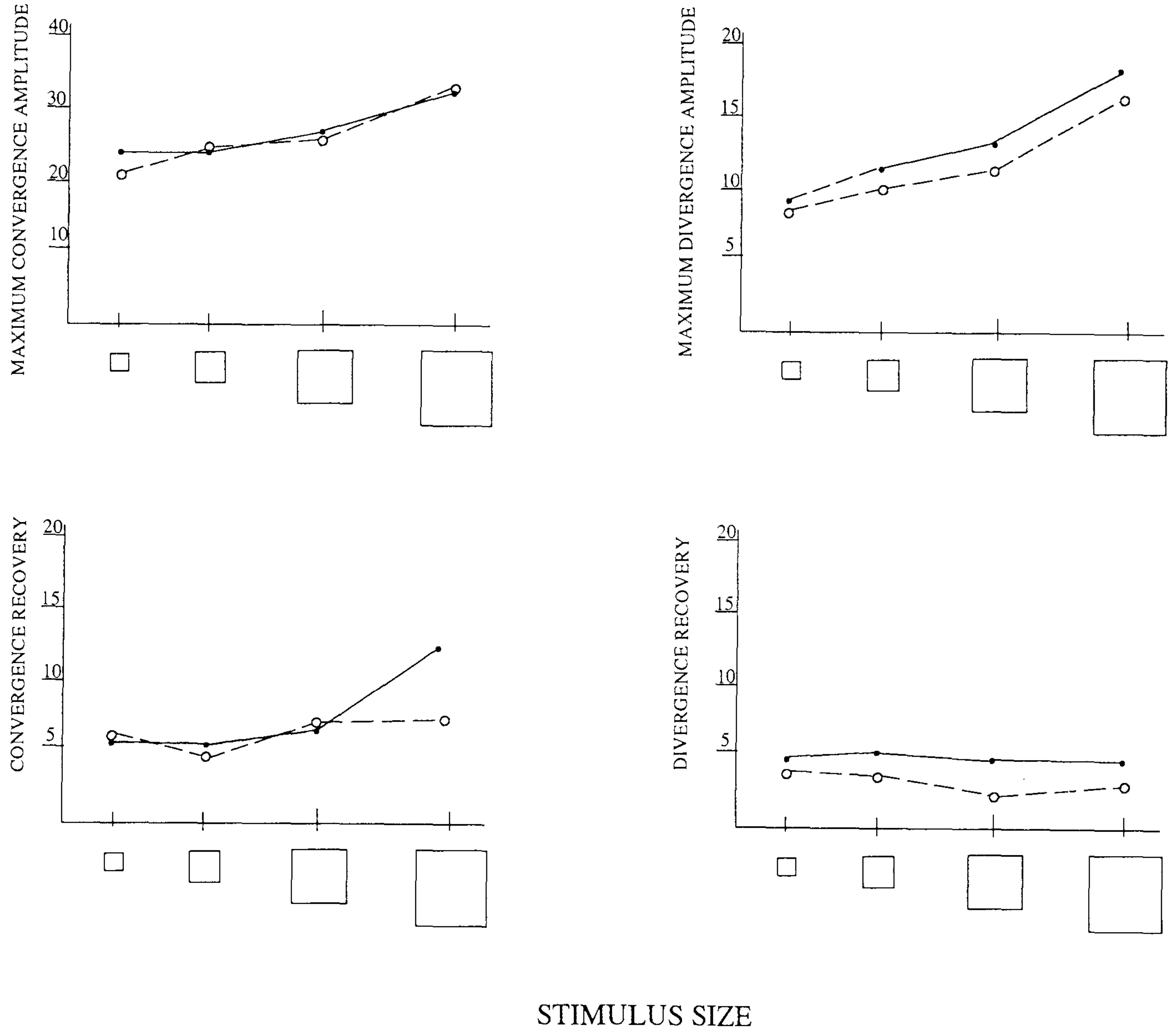

Figure 3 (Feldman et al): Effect of Stimulus Size: The top two panels depict average maximum convergence and divergence fusional amplitudes in prism diopters as a function of increases in the size of a square. The lower two panels depict average convergence and divergence recovery values. Squares with detail (dot filled) are depicted by the solid lines. Squares without detail (empty) are depicted by the dashed lines.

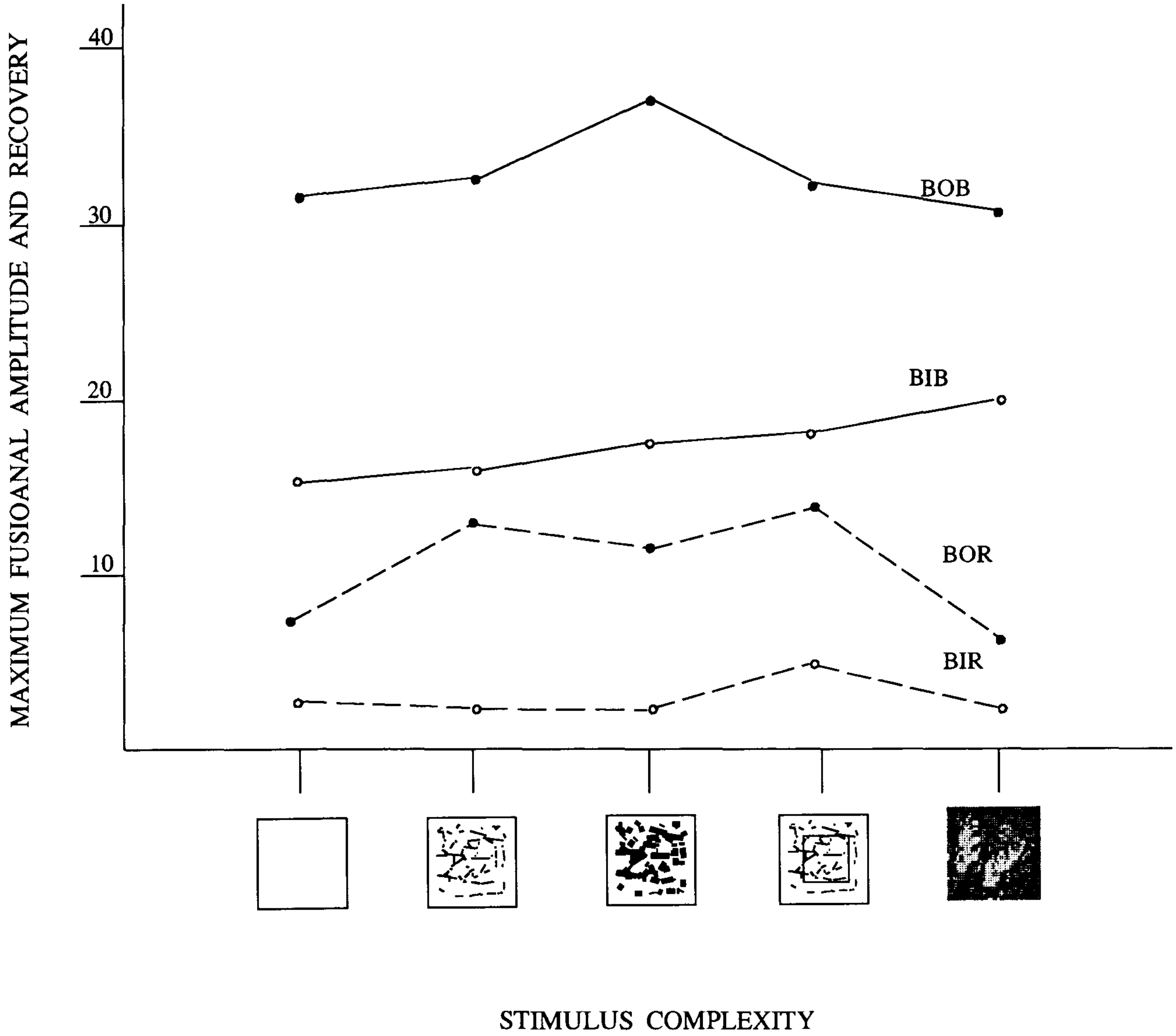

***Figure 4** (Feldman et al): Effect of Stimulus Complexity and Depth: Average maximum fusional convergence (BOB) and divergence (BIB) and average recovery values for convergence (BOR) and divergence (BIR) in prism diopters as a function of stimuli differing in complexity. The stimuli represented are: an unfilled square; a flat fusion random dot pattern; a similar pattern with double dot density; a random dot stereogram containing a crossed disparity inner square; and, a stereoscopic crossed disparity picture of a butterfly.*

RESULTS

Effect of Stimulus Size

Figure 3 (left, prior page) presents the mean maximum fusional amplitudes and refusion values during convergence and divergence for the four stimuli of increasing size. These stimuli were displayed with and without stimulus detail, i.e., the square was empty or was filled with dots.

As can be seen in Figure 3, maximum fusional amplitudes increased with stimulus size. Stimulus detail had no effect. A similar relationship appears for refusion values, although the effect is not as pronounced.

Statistical analysis revealed that maximum fusional amplitudes increased "significantly" ($p<.05$) with stimulus size. There was no such statistically "signficant" difference between empty and dot-filled squares of the same size. One way analyses of variance revealed statistical "significance" for the main effect of size for maximum fusional amplitude during convergence ($F=16.8$, $df=3$, $p<.0001$); maximum fusional amplitude during divergence($F=29.8$,$df=3$,$p<.000007$); and, refusion during convergence ($F=21.5$, $df=3$, $p<.00004$) but not divergence. Post-hoc pairwise Tukey comparisons revealed that these statistically "significant" differences were between the largest stimulus and the smaller ones.

Effect- Stimulus Complexity & Depth

Figure 4 above depicts the relationship between stimulus complexity (arbitrarily defined by five qualitatively distinct stimuli of the same size) and mean maximum fusional amplitudes or refusion values during convergence and divergence. There were no significant differences due to stimulus complexity in three of the four experiments here. Statistically "significant" (p<.05) differences were found only for refusion during convergence (F=3.82, df=4, p<.022). But, Tukey post-hoc pairwise comparisons were not statistically "significant", and thus we could not identify which, if any, of the five stimuli differed from the others.

Effect of Line Thickness

Figure 5 below shows the relationship between the seven line stimuli differing only in line width (thick-

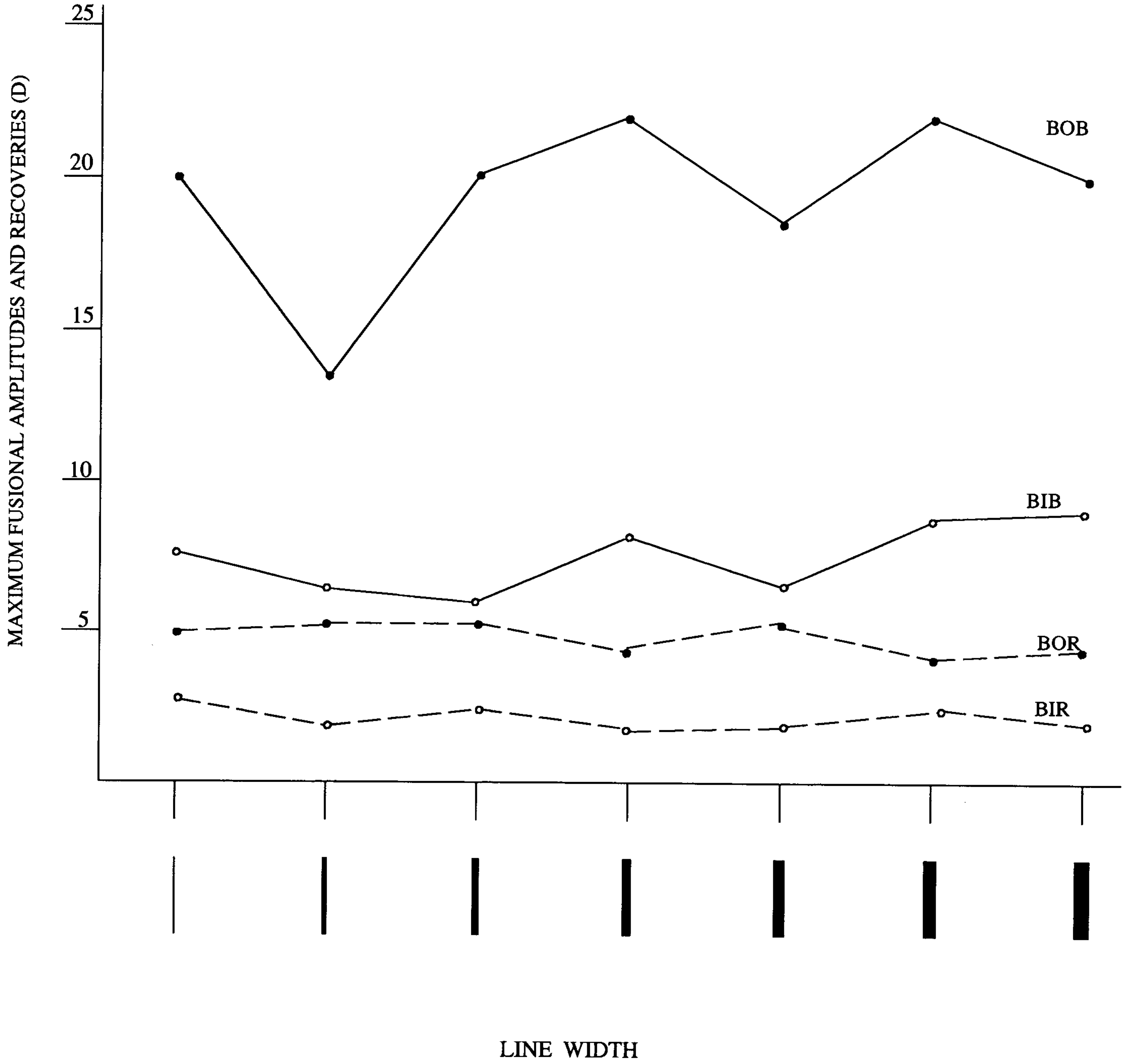

Figure 5 (Feldman et al): Effect of Stimulus Area (line thickness): Average maximum fusional convergence (BOB) and divergence (BIB), and average recovery values of convergence (BOR) and divergence (BIR) in prism diopters as a function of line stimuli increasing in width. There was no statistically significant effect.

ness) and convergence and divergence fusional amplitudes and recoveries. The only measure to reveal a statistically "significant" difference as a function of increasing stimulus line width was maximum fusional amplitude during divergence (F=4.3, df=6, p<.004). Post-hoc Tukey analyses further identified these differences as between the 0.64° and 1.42° targets (Cdiff = 1.81, p<.05), and the 0.64° and 1.73° targets (Cdiff = 2.21, p<.01).

DISCUSSION

Although Bowman and Kertesz (8) suggest that fusional amplitudes are related to stimulus complexity but not retinal disparity, (i.e., depth), careful analysis of their data do not support the conclusion that complexity alters fusional amplitude. Like Ellerbrock (5), Kertesz (6), and Bowman and Kertesz (8), we found a systematic increase in both fusional amplitudes and refusion values with increasing stimulus size. On the other hand, neither maximum horizontal fusional amplitudes nor recoveries changed with either stimulus complexity and depth or increases in line width (thickness). This suggests that the dominant factor in determining fusional amplitudes and recoveries is *not* the amount of detail of a stimulus or the total area of direct retinal stimulation, but rather the amount of retinal area contained within the boundary edges of the stimulus.

Kertesz (3,4) has suggested that if stimuli are large enough there might be a beneficial effect in stimulating sensory and motor fusion in strabismics. Our findings support his hypothesis and we also suggest that binocular vision (fusion) therapy should begin with larger targets. However, we would go one step further and recommend that such therapy should systematically progress from larger to smaller targets. In a previous study by Feldman et al (9), it was found that methods of presenting stimuli as well as the types of stimuli affected fusional amplitudes. Cooper et al (10) have also reported that systematic improvement of fusional amplitudes in normal subjects generalizes across stimuli and across method of presentations. However, patients with binocular anomalies often do not generalize their newly acquired vergence skills. They must first experience vergence stimulation using various methods of stimulus presentation and various sized stimulus targets (11). Thus, normalization of fusional vergence occurs when improved fusional amplitudes are generalized across various stimulus sizes and methods of stimulus presentation.

In summary, our results showed no differences in eliciting fusional responses as a function of stimulus complexity; as a function of simple targets having detail (dots) or no detail; or, as a function of targets having flat fusion versus depth (retinal disparity). Thus, we suggest that these stimuli may and can be used interchangeably.

Key Words
binocular vision
computer simulation
fusion
fusional amplitudes
orthoptics
reference values
stereopsis
vision, binocular
vision, test, methods
vision training

(The electronic haploscopic device described and used in this study is available from Computer Orthoptics, RC Instruments Inc, 99 West Jackson St, PO Box 109, Cicero, Indiana 46034. One author, Dr. J. Cooper, does have a proprietary interest in this instrument.)

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Abstracts in Spanish, French and German *(Continued on next page)*