THE EFFECT OF UNREPORTED VISUAL DEFICITS ON THE PROCESSING OF BRIEF VISUAL STIMULI

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Abstract

Many experiments conducted by behavioral scientists involve brief presentation of visual stimuli. These experiments frequently utilize subjects with only self-reported normal vision. It has been observed, however, that at least some of these subjects possess visual deficits that affect the processing of visual stimuli under normal viewing conditions. Experiment 1 examined whether participants with only self-reported normal vision process briefly presented visual stimuli as accurately as those with verified normal vision. Results indicate that a group with only self-reported normal vision actually possess a number of deficits at both near- and farpoint. Further, this group processed briefly presented visual stimuli significantly less effectively as compared to a group with verified normal vision. The most prevalent visual deficits observed in experiment 1 were nearpoint binocular deficits as determined by the Keystone Visual Skills Series. Experiment 2 therefore, examined the effects of specific nearpoint binocular deficits on brief stimulus processing. Results indicate that both underconvergence and overconvergence binocular deficits at near point have a significant negative effect on the processing of briefly presented visual stimuli. Overall results are discussed in terms of reducing extraneous variance factors by carefully assessing vision capabilities, particularly nearpoint binocular deficits, in experiments utilizing briefly presented visual stimuli. Implications of the findings for optometric researchers and clinicians are discussed.

Key Words

Accommodation, -brief visual stimuli, binocular dysfunction exophoria, esophoria, fusion, lateral posture, vergence,

INTRODUCTION

Numerous perceptual and cognitive experiments conducted by behavioral scientists involve brief presentation of visual stimuli. In order for a subject to adequately process such a stimulus, the visual system must be capable of gathering enough information about the stimulus in a brief period of time. It has been found however that subjects possess numerous visual deficits although they believe their vision to be unaffected.[1,2] In addition, subjects' self-report of normal vision quite often may be the sole selection criteria for obtaining subjects with supposedly adequate vision.[1,2]

REVIEW OF THE LITERATURE

The prevalence of numerous types of visual deficits in non-experimental settings is well established. A number of studies have examined the prevalence of reduced acuity at both near and farpoint in various populations. These studies indicate widespread prevalence of deficits even when corrective lenses are worn. Roberts found that 52% and 59% of the U.S. population had worse than 20/20 far and near vision, respectively. The study also indicated that even when being tested with available lenses, 34% and 43% of the population still had impaired far and near vision, respectively.[3] A later National Center for Health Statistics (NCHS) study conducted by Roberts and Rowland[4] indicated that 28% of the population had impaired far vision even in the better eye with available corrective lenses worn by the subject. A Rand[5] study focusing on refractive errors showed that 27% of their sample had a far vision impairment, 7% had a near vision impairment, and 37% had both far and near vision impairments. Overall, the Rand study found a full 66% of their sample had some type of visual impairment. Even when corrective lenses were worn, the prevalence of visual impairment was 45%. More pertinent to the present study is the observation that 47% of randomly selected university students had a measurable myopia and 30% hyperopia.[6] This finding is especially notable because numerous experiments conducted by behavioral scientists use university students as the primary or sole participants.

Binocular dysfunction deficits have been suggested to be the most common type of visual deficit after refractive errors.[7,8] Estimates of binocular dysfunction vary widely, however, most likely due to differences in assessment techniques and the comprehensiveness of the eye examination.[9] A prevalence rate of 21% has been observed in an urban optometry clinic[10] while 32.3% of a group of university students with no refractive errors demonstrated a binocular dysfunction of some type.[11] In a group of 8-12 year olds, also with minimal refractive errors randomly selected from two optometry clinics, fully 50% of a sample of 415 children demonstrated binocular dysfunction deficits.[12] Clearly, these studies suggest that binocular deficits comprise a significant percentage of visual deficits that may be present even in the absence of any significant symptoms or refractive problems.

In an explicit attempt to assess the binocular visual capabilities of the typical subject used in behavioral studies, it was found that over 46% of 140 university college students with self-reported normal vision actually had some degree of binocular dysfunction at nearpoint.[1] With the assessment instrument used, binocular dysfunction consisted of lateral posture and fusion deficits. Lateral posture refers to the directions of the lines of sight for each eye directed on a test target. Fusion refers to the extent of binocular coordination that is present. Both types of deficits can be further delineated depending on whether they involve underconvergence (exophoria) or overconveregence (esophoria). If, when an observer attempts to fixate on a target, the lines of sight converge on the test target, converge at a point closer than the test target, or converge at a point further away than the test target, then orthophoria, esophoria, or exophoria exist respectively. We propose that optimal visual processing of stimuli presented at both near and farpoint distances only occurs when normal lateral posture and fusion exist.

Numerous visual deficits including refractive errors and binocular dysfunction have been observed even in those individuals who believe they have normal vision. It has been observed that only 11.7% of 140 volunteers actually were free of any measurable visual deficit.[1] The visual assessment used in that study included acuity and binocular functioning tests at both near and farpoint. The requirements for this experiment were explicit and required self-reported normal or corrected to normal vision as a requirement for participation. The observation that potential research participants with avowedly normal vision may actually possess a number of significant visual deficits has been known for some time. Screening for visual acuity in left and right eyes at near and farpoint, Coren and Porac[2] ascertained the visual capabilities of 111 subjects with avowedly normal vision. Their surprising results indicated that 13.5% of the volunteer subjects had visual acuity's of 20/40 or below. They note that acuity of 20/40 and below is the usually accepted legal definition of impaired vision. The results also revealed that fully 42% of the subjects responded with an acuity score between 20/30 and 20/40.

Although it is evident that a number of visual deficits may be present in potential subjects, attempts to ascertain their visual capabilities prior to utilizing them in experiments involving visual stimuli have been cursory or non-existent. Coren and Porac[2] conducted a survey of 264 articles published between 1972 and 1974 in the following journals: *Perception and Psychophysics, Vision Research,* the *American Journal of Psychology*, and the *Journal of Experimental Psychology.* These articles involved a wide range of visual stimuli and presentation rates. Fully 71.6% did not specify the visual capabilities of the subjects involved. In addition, 15.9% of the articles stated only that the subjects had "normal" or "corrected to normal" vision with no mention of the tests or procedures utilized in order to determine if visual capabilities were within acceptable ranges. Only 3% of the articles actually outlined the visual tests and apparatus utilized in visually prescreening the subjects. The authors concluded that, "The researcher is making the presumption that any observer who does not wear glasses is visually normal and any observer who does wear glasses has been corrected to normal when wearing them."[2](p. 470) This caution has apparently not been heeded. Ament et al.,[1] examined the same or similar journals as Porac and Coren[2] and made the startling observation that the situation has not improved. Relatively few published articles that utilized visual stimuli presented vision assessment procedures that were comprehensive enough to determine exactly what visual abilities were assessed if any.

Previous studies[2] utilized various tests of the Keystone Visual Skills Testing Series in the Keystone Ophthalmic Telebinocular[a] to perform the visual assessments . The advantage that such an instrument has over more commonly used visual assessment techniques such as the standard Snellen charts resides in the number of visual capabilities that can be assessed, the fact that the tests are carried out under conditions of minimal stress conditions, the ease use, and the number of binocular functioning tests that are available. All the Keystone tests are conducted under binocular conditions. This assessment condition results in assessing the habitual (and "real life") response of the examinee's visual system.

These habitual response capabilities become much more important in the situation of a briefly presented visual stimulus. Upon the presentation of any such stimulus that is viewed binocularly, vergence eye movements must be completed in order to obtain proper convergence and accommodation. The latency of these eye movements is on the order of 200 ms with a relatively slow velocity and duration of 500 ms for the eyes to fixate on the target.[13] In experiments involving brief visual stimulus presentation , an abnormal habitual lateral posture of the subject could preclude the time necessary for compensatory vergence and accommodation to be performed before the stimulus is extinguished. Indeed, even with the use of an adequate fixation point presented prior to the appearance of an experimental stimulus, proper convergence and fusion may be impossible with certain types of binocular dysfunctions.

Aside from the temporal constraints concerning the convergence and accommodation abilities of the eyes, the presentation of such a stimulus in an experimental setting may include situational components that are rarely encountered in natural viewing experiences and may tax the visual system beyond what would be experienced in normal viewing. It is possible that any binocular visual deficits present in a subject may become evident or be magnified only during the special conditions of a briefly presented visual stimulus. This may explain why an individual may in fact believe his vision to be normal since under common visual demands, the binocular deficit that is present may not cause symptoms.

The effect of using subjects who believe they have normal vision but who nonetheless have measurable visual deficits is that their processing of briefly presented visual stimuli would logically not be optimal. Many if not all perceptual and cognitive experimental paradigms using visual stimuli presumably involve extraneous variability contributed by the sensory apparatus, perceptual system, response system, and cognitive processes. Any attempt to reduce extraneous variances at the initial visual processing levels by insuring normal vision capabilities in participants would result in a more adequate focus on events at higher order perceptual and cognitive levels.[14]

THE EXPERIMENTS

It is unknown whether the entire range of visual deficits that may be present in a group of self-reported normal vision participants significantly impairs the processing of brief visual stimuli compared to verified normal vision participants. Experiment 1 examines this issue. Experiment 2 examines nearpoint underconvergence and nearpoint overconvergence on the processing of brief visual stimuli. It is unknown whether both underconvergence and overconvergence nearpoint binocular deficits negatively impact the processing of brief visual stimuli at distances typically used in experiments.

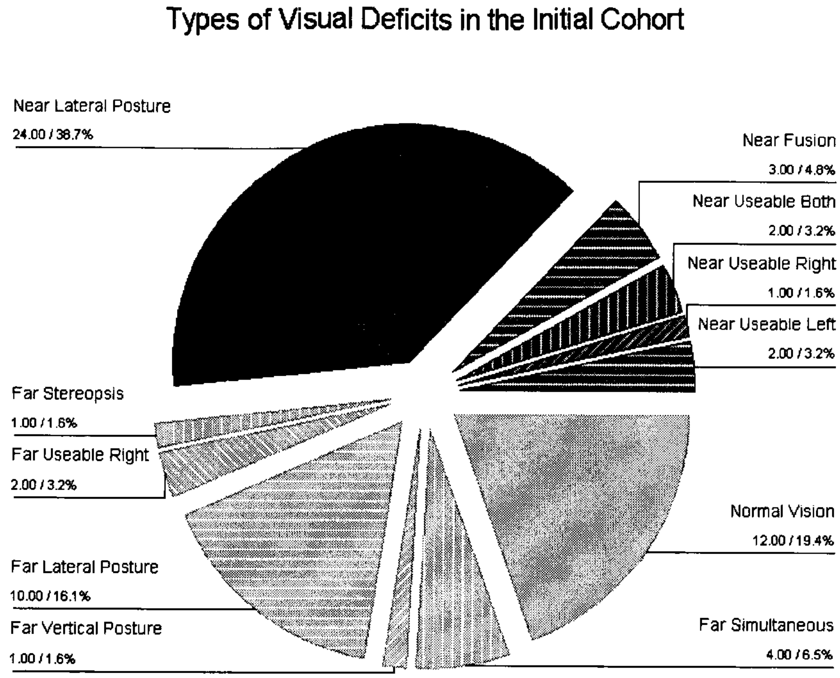

Figure 1. Visual deficits present in all pre-screened participants in the initial subject pool.

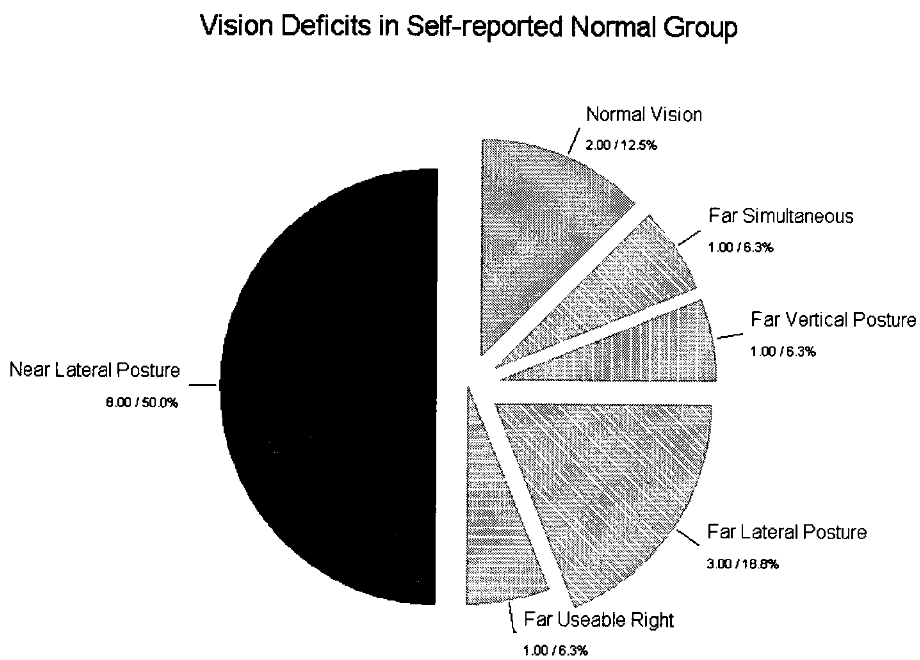

Figure 2. Visual deficits present in the self-reported normal vision group in experiment 1.

Experiment 1

Method

Participants. Forty-seven volunteer students, all with self-reported normal vision, were initially visually tested and assessed (see Apparatus below). This number was necessary in order to identify and obtain the needed number of subjects with verified normal vision for the experiments. Figure 1 presents the distribution of specific deficits that were observed in the initial subject pool. Numerous subjects had multiple deficits. For Experiment 1, Group 2 consisted of ten subjects randomly selected from the initial pool with self-reported normal vision, regardless of actual deficits that were present. Figure 2 presents the actual deficits present in Group 2. Only two of the randomly selected avowedly normal vision subjects actually possessed unimpaired vision and numerous subjects had multiple deficits. Group 1 consisted of ten subjects selected from the initial subject pool with verified normal vision. Two subjects in Group 1 and 3 in Group 2 had corrective lenses. There were 12 female and 8 males and their age ranged from 18 to 33 (M = 23. 4, SD = 4.96). Participants may have received extra course credit or fulfilled a course requirement for their participation. For all participants, it was explicitly requested prior to participation that they possess normal or corrected to normal vision and that English be their first language. Informed Consent was obtained from all participants and all were treated in accordance with the American Psychological Association's ethical principles.

Apparatus. A Keystone Ophthalmic Telebinocular with the Keystone Visual Skills Series[a] farpoint Test 1 through Test 7 along with nearpoint Test 10 through Test 14 was used in order to ascertain the actual visual capabilities of all subjects. An overview of the individual far and nearpoint tests is presented in the appendix. Stimulus letters used in a simple letter identification task were presented on a computer controlled 15-inch diagonal color monitor screen for a period of 50msec. The stimulus letters were preceded by a central fixation point that appeared for 1sec. A BASIC language computer program using assembly language timing routines was used for the timing and presentation routines. The stimulus letters were also printed on paper providing a hard copy record of the randomly generated stimulus letters. Subjects' verbal identifications were recorded with a tape recorder.

Stimuli. Five-letter horizontal displays were centered on the color monitor. The letter for each position was randomly selected from the consonants of the English alphabet and letters were separated by blank spaces. The CRT monitor background was dark while the letters were white. The letters and spaces were 5mm in height and 5mm in width and subtended a visual angle of 0.7° at a distance of 40cm. The entire display of 5 letters with spaces was 50 mm and subtended a visual angle of 7.0°. The fixation point consisted of a filled block and measured 5mm by 5mm. The block subtended a visual angle of 0.7° at 40cm. An illuminated blank screen was presented immediately following the stimulus presentation. This display served as a mask to eliminate the phosphor decay problem inherent in the use of CRT monitors as display devices.

Procedure. Vision abilities were assessed using the Keystone apparatus, as described above. After the visual assessment, participants were seated in a small room with the visual assessment apparatus, computer, printer, tape recorder, and the CRT monitor. The subject was seated in front of the computer controlled CRT monitor at a distance of 40cm with the center of the CRT monitor at eye level. A chin rest was used to ensure subjects maintained proper head and eye positioning. The 40cm distance was selected because that is a typical distance used in experiments using visual stimuli and because it closely corresponds to the near fixation point. The subjects were then given the instructions pertaining to the task and the required response. At that point, the subject was given 10 practice trials, followed immediately by 25 experimental trials. Each trial consisted of the presentation of the fixation point centered on the CRT for 1sec followed by the 5 stimulus letters for a period of 50msec. The stimulus letters were followed immediately by a full screen illuminated block mask for a period of 500msec. The interstimulus interval was 5sec. Following the cessation of the stimulus and before the start of the next presentation, the subject verbally reported what letters were presented. The vocal response was recorded. The stimulus letters that appeared on the computer controlled CRT were also printed on paper for use in later analyses.

Table 1.
Letter Identification Scores for Verified Normal and Self-reported Normal Groups in Experiment 1.

Vision Type	M	SD	SE	n
Verified Normal	73.8	15.26	4.82	10
Self-reported Normal	58.2	16.35	5.17	10

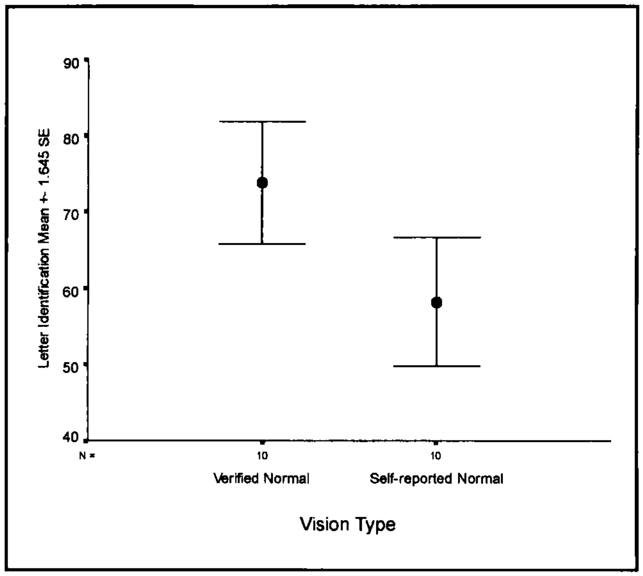

Figure 3. Mean letter identification scores for verified normal and self-reported normal vision groups in experiment 1.

Results

Table 1 and Figure 3 show that the mean identification rate for the groups differed with the verified normal vision group highest (M = 73.8, SD = 15.26), compared to the self-reported normal vision group (M = 58.2, SD = 16.35). The results of an independent one-tail t-test performed on the two groups indicated that the visually normal group identified significantly more letters than the self-reported only normal vision group, $t(18) = 2.205$, $p = .025$.

Discussion

Results of experiment 1 indicate that a number of visual deficits are present in those who believe their vision to be normal. Additionally, Experiment 1 clearly shows that self-reported normal vision and verified normal vision may not be equivalent criteria in terms of subject selection. This discrepancy has the potential of significantly impacting obtained results. Given that the experimental task required relatively low cognitive demands in terms of letter identification only, one may assume that the significantly higher rate of letter identification observed in the verified normal vision group was due to significantly better processing at initial sensory processing stages.

Experiment 2

Method

Participants. Twelve subjects with verified normal vision were selected from the initial pool of forty-seven university undergraduate student volunteers and formed Group 1. Additionally, fourteen subjects with an underconvergence near-point lateral posture deficit and eight subjects with an overconvergence near-point lateral posture deficit were identified and formed Groups 2 and 3 respectively. Of the 34 final participants, 16 were male and 18 were female. The age of the subjects ranged from 18 to 36 with a mean age of 22.3 (SD = 5.51). Thirteen of the subjects wore glasses. For all participants, it was explicitly requested prior to participation that they possess normal or corrected to normal vision and that English be their first language. Participants may have been able to use the research experience to fulfill a course requirement or for course credit in exchange for their participation. Each participant was treated in accordance with the APA Ethical Guidelines and informed consent was obtained.

Apparatus and Procedure. The same equipment, stimuli, and procedures used in Experiment 1 were used in Experiment 2.

Results

Table 2 and Figure 4 show that the letter identification means for the three groups differed with the verified normal group highest (M = 75.42, SD = 14.44), the underconvergence (exophoric) binocular deficit group next (M = 55.78, SD = 18.05), and the overconvergence (esophoric) binocular deficit group lowest (M = 50.37, SD = 15.13). Due to uneven groups sizes, the Levene statistic test for homogeneity of variance was performed and indicated no significant violation of the assumption of homogeneity of variance for the planned one-way ANOVA, LS(2,31) = .201, p =.819). The results of the one-way ANOVA procedure performed on the three groups shows that there was a significant difference between groups, F (2,31) = 7.19, p = .003). Bonferroni post hoc analysis indicated that the verified normal vision group identified significantly more briefly presented letters than either the overconvergence or the underconvergence binocular deficit groups, p=.013 and .006 respectively. The overconvergence and the underconvergence deficit groups did not differ from each other (p = .793).

Discussion

The results of Experiment 2 indicate that both underconvergence and overconvergence binocular deficits at nearpoint have a significant negative impact on the processing of briefly presented visual stimuli. The importance of this finding is underscored by the fact that the visual task was not a demanding task in terms of perceptual and cognitive demands and involved letter identification only. In addition, the relatively small sample sizes suggest that the effect of binocular nearpoint deficits is striking.

Discussion and Summary

Our initial screening indicates that a number of visual deficits can be assessed and identified in those who believe their vision to be normal. Additionally, the ability to process briefly presented visual stimuli was negatively affected by these deficits in both experiments. One may assume that the verified normal vision group is processing the visual information at initial sensory processing stages better than the avowedly normal group in Experiment 1 and the near-point binocular deficit groups in Experiment 2. It is not known if any other deficits at near and farpoint shown to be present in avowedly normal vision subjects also significantly affect brief stimulus processing. Additional studies designed to investigate this question are underway in our laboratory. It may be the case that only specific deficits negatively impact brief stimulus processing. If that were the case, researchers would benefit by assessing and identifying only those deficits and may be able to utilize subjects that may possess innocuous visual problems.

In behavioral paradigms attempting to assess higher-order perceptual or cognitive processes, failure to accurately select subjects with true normal vision clearly has the potential to add significant extraneous variance to the paradigm. The subjects in this study are representative of the type of subject typically utilized in many behavioral science experiments, specifically, young undergraduate students. What is important is that the visual assessment technique utilized does indeed identify important visual deficits, particularly nearpoint binocular deficits, that may interfere with adequate visual processing and that the assessment technique is economical in terms of time and expertise required to perform the assessment.

In both experiments, the variance and standard deviation of the verified normal groups did not differ significantly from the avowedly normal vision group in Experiment 1or the underconvergence and overconvergence binocular deficit nearpoint groups in Experiment 2. The significant differences between the verified normal vision group and the visually impaired groups in both Experiment 1 and 2 would then functionally become a source of extraneous variance in a study involving brief presentation of visual stimuli that did not adequately assess visual capabilities in subjects prior to participation. The "maxmincon" principle presented by Kerlinger[15] states that a researcher should attempt to maximize systematic variance, minimize error variance, and control extraneous systematic variance. Excessive extraneous variance present in an experiment, even if "equally" distributed among groups, may have the potential of masking the effect of the true independent variable. This may be particularly problematic in cases where the effect of the independent variable is weak.

As demonstrated in these experiments, previous research involving brief visual stimuli have utilized subjects with avowedly normal vision but who nonetheless may have possessed visual deficits that may have interfered with visual processing. A way to reduce this source of extraneous variance would be to assess adequately the subjects' visual capabilities, particularly nearpoint binocular abilities, prior to any experiment involving brief presentation of visual stimuli. As initially suggested by Coren and Porac[2] researchers would do well to report the specific tests used to assess visual capabilities, including those for binocular deficits at nearpoint.

The results of these experiments also have implications for optometric re-

Table 2.
Letter Identification Scores for Verified Normal, Underconvergence and Overconvergence Binocular Deficit Groups at Nearpoint in Experiment 2.

Vision Type	M	SD	SE	n
Verified Normal	75.42	14.44	4.17	12
Under-convergence	55.78	18.05	4.82	14
Over-convergence	50.37	15.13	5.35	8

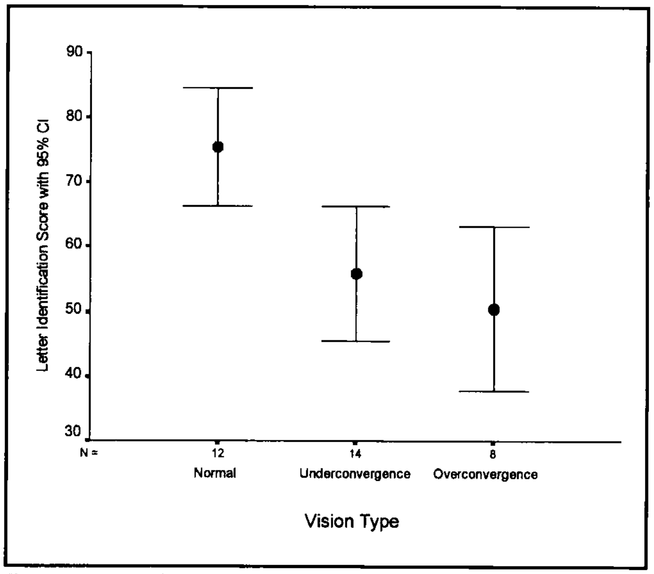

Figure 4. Mean letter identification scores for verified normal, underconvergence, and overconvergence binocular deficit groups at nearpoint in experiment 2.

searchers and clinicians. Thus, standard procedures to assess nearpoint phorias, such as the cover test and prism dissociation methods, might not give the same results as under the binocular, more "real life" conditions that the Keystone apparatus provides. While this might seem evident to many behaviorally oriented optometrists, research to determine this assumption is needed. Further, our results give support to the negative effect that uncompensated nearpoint phorias can have on visual information processing, at least for briefly presented stimuli, such as are used in tachistoscopic training.

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Sources

a. Keystone View. 340 Western Road, #1 Reno, NV 89506

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Appendix
Keystone Visual Skills Series Tests

Farpoint Tests

1. Simultaneous Perception: A gross suppression test.
2. Hyperphoria: A test for vertical imbalance.
3. Lateral Phoria: A test of lateral posture and postural stability.
4. Binocular Coordination: A test of fusion facility.

4.5 Binocular Acuity: Usable vision under fusion.

5. Usable Vision-Right Eye: A test of monocular discrimination under fusion.
6. Usable Vision-Left Eye: Same as Test number 5.
7. Stereopsis: A test for loss of depth awareness.

Nearpoint Tests

10. Lateral Phoria: Same as Test 3.
11. Binocular Coordination: Same as Test 4.
12. Binocular Acuity: Usable vision under fusion.
13. Usable Vision-Right Eye: Same as Test 5.
14. Usable Vision-Left Eye: Same as Test 5.