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The effect of induced changes in dioptric and binocular vergence or fixation disparity on performance of a visually directed task

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Abstract

The investigators utilized the Stroop color naming paradigm as a tool to monitor visual performance under various optical conditions (plus and minus lenses and base in and base out prisms). Decreases in performance on the experimental task would indicate (hypothetically) an increase in nearpoint visual stress and/or decreased attention to the task. Subjects were screened for visual acuity, stereopsis, and fixation disparity while looking through habitual lens prescriptions, if any, and through +2.00 and -2.00 diopter lenses and 6 prism diopter base in and base out prisms. The 20 subjects passing criteria were then trained and subsequently tested on a computerized version of the Stroop color naming task while viewing through the various lenses and prisms as well as the habitual prescription. Data analysis attempted to relate changes in fixation disparity, convergence, or dioptric vergence to changes in performance on the visually directed Stroop task. No significant results were obtained and hence, within this paradigm, one cannot conclude that short-term induced changes in fixation disparity, convergence, or dioptric vergence are related to performance on a visual discrimination task.

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THE EFFECT OF INDUCED CHANGES IN DIOPTRIC AND BINOCULAR VERGENCE OR FIXATION DISPARITY ON PERFORMANCE OF A VISUALLY DIRECTED TASK

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ABSTRACT

The investigators utilized the Stroop color naming paradigm as a tool to monitor visual performance under various optical conditions (plus and minus lenses and base in and base out prisms). Decreases in performance on the experimental task would indicate (hypothetically) an increase in nearpoint visual stress and/or decreased attention to the task.

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Introduction

Many clinical cases have indicated that learning ability (as judged by parents, patients, and educators) often improved after prescription of reading lenses or vision training (Birnbaum, 1984). Assuming validity of these claims, one may postulate that some visual aspect related to learning performance is enhanced by the lenses or training. Apparently, some ability or group of abilities of the visual system is prevented from optimum function by some factor before intervention. This factor will be referred to as visual stress.

Although little convincing non-clinical research exists to explain the above contention, Pierce (1966 and 1968) indicated that, during specific visual tasks, carefully prescribed near-point lenses could lead to a decreased metabolic rate and a change in body posture. Greenspan (1970), utilizing a timed, visual discrimination task, found that use of near-point lenses was related to enhanced performance. Although one must be careful to not over generalize, these studies supported the hypothesis that some sort of stress present during near work may be alleviated by optical means.

Birnbaum (1984) suggested that nearpoint visual stress arises from a mismatch between the autonomic and somatic nervous systems due to general stresses inherent in either the specific task or the environment. Given this model, one may postulate several measurable intrinsic variables (heterophoria, vergence ranges, or accommodative posture) possibly associated with visual stress on specific tasks. Sheedy (1980) indicated that fixation disparity might be an indicator of this stress. This possible relationship was examined further in the present study.

In more general terms, Kahneman (1973) looked at performance from an attentional point of view. An individual's capacity to attend (at any moment in time) is finite. Within limits, more attention paid to a specific task will help maximize performance on that task. Stresses, however, tend to consume some attention and, therefore, reduce the total attention available for performance. Consider, for instance, a visually aware young optometry student taking the written portion of his preferred state board exam (a definite source of stress). Several potential stressors (both visual and non-visual) are inherent in this task. If these stressors are not partially controlled they may prevent constructive concentration of attention on the task at hand (namely passing the board exam). Within this present construct, visual stress (perhaps related to fixation disparity) may deplete a portion of the available attention for a visual task, therefore reducing performance on that task. Optimum optical conditions help to reduce this stress and therefore lead to enhanced performance.

To test this construct, a task was necessary which allowed monitoring of subject performance under various optical conditions (designed to be analagous to binocular conditions which cause visual stress). If the proposed stress factor and attentional interraction exists, one could expect differential performances related to the optical conditions. Criteria for this task were that it require visual input, provide for measurable performance, and require verifiable use of attention.

One such task, well accepted in cognitive psychology, is the Stroop color-naming task (Kahneman, 1973; Keele, 1973). A general explanation of this task follows.

Suppose a subject viewed the word "RED" printed in green ink (dissonant color pairing). If asked under temporal pressure for the color of the print, the subject would mentally separate the word's meaning from its actual color before responding. This dual processing would lead to a hesitation. If given a list of several such dissonant color words and asked to tell the print color sequentially as rapidly as possible, the subject would mentally separate semantics from print color for each word before verbalizing it and proceeding to the next word. Performance could be monitored by determination of how many stimuli the subject correctly called in a given time. Whether this phenomenon is due to input inefficiencies as proposed by Klein (1963) or response competition as hypothesized by Hintzman, et al (1970), the Stroop task presents two conflicting (dissonant) variables for each word. According to Keele (1972) "when the processing of one stimulus interferes with processing another, the processing is said to take attention."

To determine whether such interference took place, subjects were timed while performing tasks on non-dissonant stimuli (reading white, color-denoting words or verbalizing the color of colored bars). Performance on those tasks was compared with performance on a list of dissonant stimuli. Subjects consistently called more non-dissonant stimuli in a given amount of time by an average ratio of approximately five to three, thus indicating that the dissonant condition required more attention than did the non-dissonant condition.The Stroop task, then, was determined to fulfill the previously listed criteria and was deemed a valid tool for assessment of relative visual stress.

For determination of relative visual stress levels under various optical conditions, subjects performed the Stroop task at 40 cm while looking through the following (all over habitual lens prescription, if utilized.):

1. Plano lenses
2. +2.00 diopter lenses
3. -2.00 diopter lenses
4. 6 prism diopter base in prisms
5. 6 prism diopter base out prisms.

Fixation disparity associated with each viewing condition was determined prior to the experiment. If, as Sheedy (1980) suggested, fixation disparity is related to visual stress, the fixation disparity measures could serve as an index of performance under specific visual conditions. The researchers hoped to answer the following questions:

1. Do optical conditions change visual performance and therefore mimic the presence of modifiable visual stress?
2. Is fixation disparity useful in predicting relative visual stress?

Materials

The screening materials included a reduced Snellen chart to determine 40 cm visual acuity, a vectographic RANDOT stereogram to measure stereopsis at 40 cm, and a Vision Analysis Disparometer (as described by Sheedy, 1980) equipped with a clear acetate overlay containing an array of horizontal lines for accommodation control to obtain lateral fixation disparity data at 40 cm. Lenses (plano, +2.00 diopters, and -2.00 diopters) and prisms (6 prism diopters base in and base out) mounted in standard Bernell white plastic lens holders were used in screening and experimental conditions. A forehead rest was used to maintain a subject-to-target distance of 40 cm. An adjustable stand held the lens holders, maintaining a constant 12 mm vertex distance and 10 degree pantoscopic angle.

Stimuli were displayed on a 13 inch (diagonal) Amdek color monitor controlled by a Commodore 64 computer with disc drive. All stimuli appeared in upper case letters, each consisting of an 8 x 14 dot matrix subtending 3.75 minutes visual angle at the spectacle plane (20/75 acuity demand).

The computer program was set up in 3 levels listed below according to characteristics:

1. Color names presented in white letters (non-dissonant)
2. Colored bars (non-dissonant)
3. Color names presented in conflicting colors (dissonant).

Within each level were three 11 x 15 stimulus arrays, each of which provided a display which filled the entire monitor screen.

Sample programs included examples of all levels. These programs and levels 1 and 2 were used to familiarize the subjects with the colors, the color names, and the nature of the task before the experiment.

Procedure:

31 students from Pacific University were screened with 20 passing all the following 40 cm test criteria for subject selection:

1. Habitual near Snellen acuity of at least 20/20 OD, OS, and OU.
2. Habitual stereoacuity of at least 30 seconds of arc.
3. Habitual fixation disparity* between 9 minutes exodisparity and 4 minutes esodisparity.
4. Induced change in fixation disparity* as shown in Table 1.**

*An average of two measurements obtained by the method of limits.

**These values were not actually criteria. The researchers wanted subjects which tended to increase exodisparity through (+) and base out while increasing esodisparity through (-) and base in. These data were analyzed to determine that the selected pool behaved as expected. The 20 subjects which came CLOSEST to possessing these characteristics were chosen for study. Selected subjects showing aberrence in one condition did not show aberrence in any other condition.

TEST CONDITION	RANGE OF INDUCED FIXATION DISPARITY CHANGE (minutes)
+2.00	2 eso to 18 exo
-2.00	1 eso to 22 eso
6 BI	0 to 14 eso
6 BO	1 eso to 16 exo.

Table 1: Range of induced change in fixation disparity for each test condition.

The experimental group consisted of 13 males and 7 females aged from 19 to 40 years with a mean age of 24.7. Subjects received five dollars compensation upon completion of participation.

The selected experimental subjects first viewed the sample programs. The experimenter verbally denoted the colors and insured that the subjects could identify each. One array each of levels one, two, and three was used to familiarize the subject with the task. This was done by having the subject perform "mock runs" while believing that the experiment had begun. Subjects were informed of the following before each mock performance:

1. (level one only) The display would consist of color-denoting words printed in white. The task was to read the words sequentially.
   (level two only) The display would consist of colored bars. The task was to name the colors sequentially.
   (level three only) The display would consist of color-denoting words printed in conflicting colors. The task was to verbalize the print color for each word sequentially.
2. The display would go blank after a preset time.
3. Score would depend upon correctly verbalizing the color (name of the word for level one, color of print for levels two and three) of as many of the words (or bars) as possible before the display blanked.
4. Speed was important but accuracy was crucial.

5. Mistakes of which the subject was aware should be corrected before continuation.
6. Print should be kept clear. If the subject failed to keep the print clear he should indicate so.

After familiarizing the subjects with the procedure, the above list was again emphasized. The experimental data were derived from presentation of a total of 7 displays of level 3 (chosen from the 3 available level 3 arrays in random order). Subjects verbalized print color while viewing through the lenses or prisms (also in random order, except that the plano lenses were utilized for the 1st, 4th, and 7th trials). Score for each display was determined by the number of colors correctly verbalized in the 25-second display time.

Results

For purposes of interpreting the results tabulated below, probabilities, calculated by analysis of variance (Snedecor and Cochran, 1967) were considered statistically significant if $p \leq 0.05$.

As shown in Table 2, the fixation disparity, although following the basic pattern expected for a normal population (Ogle, et al, 1967), showed much variation. A general pattern appeared to exist in that the conditions promoting more esodisparity yielded better performance. These relationships, however, were not statistically significant.

Condition	Mean Induced Fixation Disparity	Fixation Disparity - Standard Deviation	Mean Performance (Words called correctly)	Performance Standard Deviation	Mean Change In Performance (Compared to Plano)
PLANO	+2.50	4.00	38.04	5.41	N/A
+2.00	-3.65	5.97	36.94	7.45	-1.10
6 BO	-6.20	4.85	37.40	7.47	-0.64
6 BI	+4.15	4.54	38.38	5.22	+0.34
-2.00	+6.55	4.68	38.64	5.25	+0.60

[Sign convention for fixation disparities: (+) = esodisparity.]

Table 2: Means and standard deviations (group data) relating optical conditions to induced fixation disparity (minutes of arc), Stroop performance, and change in perfomance

Tables 3, 4, and 5 relate induced fixation disparity, habitual fixation disparity, and induced change in fixation disparity to performance, respectively. The only significant value is seen for 6 prism diopters base in in Table 4. This value indicates that those with higher exo (or lower eso) habitual fixation disparity tended to increase their performance with the prism more than did those with higher eso (lower exo) fixation disparity. The correlation coefficient, however, shows minimal correlation.

CONDITIONS	+2.00	6 BO	6 BI	-2.00
CORRELATION	0.110	0.364	-0.173	0.230
PROBABILITY	0.322	0.057	0.233	0.164

TABLE 3: Correlation coefficients of Stroop performance and *induced* fixation disparity under various optical conditions.

CONDITIONS	+2.00	6 BO	6 BI	-2.00
CORRELATION	0.018	-0.112	-0.409	-0.365
PROBABILITY	0.47	0.32	0.037	0.057

TABLE 4: Correlation coefficients of observed change in Stroop performance (as compared with performance through plano) under various optical conditions and *habitual* fixation disparity.

CONDITIONS	+2.00	6 BI	6 BO	-2.00	ALL
CORRELATION	-0.089	0.269	0.040	-0.326	0.118
PROBABILITY	0.355	0.126	0.427	0.080	0.149

TABLE 5: Correlation coefficients of observed change in observed changes in Stroop performance with observed *change* in fixation disparity

Conclusion / Discussion

On the basis of our results, one cannot conclude that convergence, dioptric vergence, or fixation disparity is related to performance of a visually directed task within the constraints of this experiment. All limitations of small sample experiments apply to this experiment. Another problem was the lack of validation of the appropriateness of the specific lenses and prisms. Research in progress seeks to relate functional criteria for near-point prescriptions (slope prescriptions, MEM, and others) to performance. This research will utilize a progression of Stroop displays, advanced by the subject, to increase task time and therefore amplify any differences in performance. Subjects will wear the experimental lenses or prisms for a specified time before each trial to increase manifestations of stress. Other researchers may want to utilize tasks more nearly reflecting real-life situations, such as reading comprehension tests. Also, fixation disparity slopes and curve types should be considered to insure more equal responsivity of the subjects to the various optical conditions.

Many optometrists make positive claims about near-point lenses. This research attempted to validate those claims and relate them to fixation disparity measurements. Although no convincing results arose, one should remember that the sample was small, no clinically valid criteria were used to arrive at specific lenses or prisms relative to each subject, and that the task time was short. Further research, with compensations for the above mentioned limitations, will shed more light on the question of whether functional near-point lenses affect visual performance.

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