IMPROVING STEREOSCOPIC ACUITY IN PLOTTER OPERATORS

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ABSTRACT

Of the necessary attributes of any stereoplotter operator, the most important is the ability to discern small changes in elevation. Preliminary tests in vision training performed at Ferris State College on the Howard-Dollman apparatus and on the Wild A-7 indicate that visual acuity can be improved even for those individuals who exhibit normal stereoscopic vision. This vision program has two benefitial results. First, the organization receives immediate results since individuals with weak stereopsis are identified. Secondly, improvement in stereoscopic vision should lead to a more accurate map product. An experimental program of vision training is presented to show how this improvement has been accomplished.

BACKGROUND

With the creation of the Center for Photogrammetric Training at Ferris State College, an interest in the stereoscopic abilities of plotter operators developed within the College of Optometry. This interest was sparked by the initial requirement of having photogrammetry students submit to eye examination to ensure that stereoscopic vision was present. It was well known that individuals who exhibited normal stereopsis in a latent state could, with training, achieve normal or near normal stereoscopic vision. The question that began to surface was could vision training improve the stereoscopic acuity of an individual who already possessed normal stereoscopic vision. If it could, then one might expect that the novice photogrammetry student should become competent at the photogrammetric tasks quicker and with a higher precision. This precision would come from the operation of their binocular system at a high level of efficiency. This in turn should lead to individual satisfaction in performing the required photogrammetric tasks.

STEREOPLOTTER OPERATOR TASKS

Saladin and Rick [1982b] identify two tasks required by the stereoplotter operator. The primary task lies in the area of profiling, contouring, and search and detect operations. These depend upon the excellent functioning of stereopsis and visual function. Different visual capabilities are required for the secondary function which processes data collected in the first task. This would involve items such as accommodation (change of focus), maintaining focus, and perception of small chromatic differences within the medium. It is the first task which has created problems in photogrammetry training to date.

To meet the requirements of these tasks, a vision training program was developed. In addressing this need, it is necessary to distinguish between stereoscopic quantity and quality. Quantity can be thought of as the stereoscopic threshold under ideal conditions without any time constraints. This threshold involves the detection of horizontal parallax and the utilization of these parallax differences in perceiving depth. Quality, on the otherhand, is the practical concept in which a high level of stereopsis is required over a long period of time and under a myriad of conditions. Therefore, the goal of the vision training program must be the development of quality in stereoscopic acuity. To achieve this goal, an initial categorization of individuals is required from which a training program can be developed.

CATEGORIZATION OF PLOTTER OPERATORS

It should be pointed out that if no stereopsis is in existence, vision training can not establish that ability. Thus, three categories have been identified and they are:

a) Category I - This category is designated for those individuals who have no visual handicaps that are detrimental to the successful completion of the photogrammetric tasks.

b) Category II - Classification of an individual in this category indicates that the person has the potential vision capabilities to perform the photogrammetric tasks but that additional vision training or spectacle correction is needed to upgrade to Category I. Before upgrading, each individual would require vision examination.

c) Category III - All individuals within this category exhibit uncorrectable handicaps to vision and they should not be given positions as stereoplotter operators.

The screening process used to categorize candidates is not the standard procedures utilized in general vision testing but is specially designed to test finer vision dysfunctions. In addition, the categorization necessitates an understanding of what constitutes a handicap to normal stereoscopic vision and which of these handicaps can be corrected.

FINDINGS FROM OPERATOR INTERVIEWS

The problems of correct stereoplotter optical ajustments and the quality of vision were discovered by Saladin and Rick [1982b] in on-site interviews with photogrammetrists at one U.S. government mapping installation. These findings are summarized as follows.

1. There were fewer complaints from older photogrammetrists. Part of this is explained through the natural attrition process in which employees who had vision problems left stereophotogrammetry. The second reason is that as age increases, there are fewer working components in the visual system, therefore, with a simpler system, there is less that can go wrong with the stereoscopic process. These older employees did indicate that blurring of the floating mark did occur after several hours of stereo work. Among the younger workers, they frequently mentioned discomfort in focusing and the difficulty in maintaining a single image.

2. For employees operating the Bausch and Lomb Zoom 240 microscope, heat and the ability to maintain a stereoscopic view over a long time were frequent complaints. The physical discomfort of heat does affect vision and this can easily be corrected by directing the heat away from the operator. This merely points out how varied are the factors which enter into the process. The second complaint deals with the orientation of the photographs for stereovision tasks. If any error existed during the orientation of the photographs, the eyes would make up for the small misalignment. But when the operator looked up from the model and then back into the microscope, they had difficulty in finding their first point of observation or may not have been able to see stereoscopically. Even a small misalignment (vergence requirements) can significantly degrade stereo acuity.

3. There was a considerable variation in time until an individual felt confident of their ability. This was measured as the time needed before the individual felt capable about arguing an opinion on a stereoscopic position. While some said this took

several days, the majority felt it took "several weeks to two months". Among younger persons, some felt that if they were removed from stereoscopic tasks for a period of time (a week or more), that several days were required to build up their confidence again. This reinforces the psychological component involved in stereopsis.

4. Time also plays an important role in measuring an individual's stereoscopic ability through the day. Most interviewees felt that six hours is about the limit for stereoscopic work during a shift. Younger employees almost all found that efficiency fell off after lunch. While older employees complained of body discomfort, the younger operators complained of visual and mental fatigue which included "blurring of the model, inability to maintain single vision, a flattening of the terrain whereby the stereoscopic percept fades away, and difficulty in adjusting the accommodative (focussing) mechanism from the model to an object outside the stereoscope". Also, some bifocal wearing (presbyopic) employees found blurring of the measuring mark during the day. Most probably this is due to improper setting of the eye pieces within the plotter to a less than optimum setting.

5. During the interviews, it became apparent that many employees did not understand the instrument adjustments available to accommodate the individual's visual characteristics. It was also found that some did not fully understand the difference in "optical parallax" and "model parallax". Other instrument adjustments also were not widely known or utilized and the most significant is the simultaneous focusing of the floating mark and the terrain. This, and other instrument maladjustments with respect to the optical viewing system, raise questions as to the validity of these optical observations. Finally, although some training is performed of new employees, there appears to be little knowledge of instrument measuring theory.

While these findings are valid for this specific on-site investigation, it is probable that similiar complaints can be found within many mapping organizations. These results indicate that for effeciency, accuracy, and personnel job satisfaction, a vision training program, coupled with an explanation of the theory of the practical usage of photogrammetric instruments are needed.

VISION TRAINING EXPERIMENT

In an attempt to study the problem of vision training, an experimental program was developed at Ferris State College. Two groups of individuals, one a control group and another experimental, were paired by matching subjects who exhibited similar optical and binocular characteristics as determined through the clinic at the College of Optometry. Any significant refractive errors were corrected prior to the investigation and the initial pairings were concealed from the principal investigator.

Three different devices were utilized to measure the stereoscopic acuities of both groups. The first was the Howard-Dolman peg apparatus which consists of an elongated box which contains two black pegs. The right peg is moved back and forth until it is at the same distance from the operator as the fixed left peg. The second test was the Keystone Multi-Stereo test. This apparatus consists of a stereoscope in which three cards of stereo pairs are inserted. Each card contains a row of black vertical lines. The observer is to compare these lines going from left to right. The angular disparity decreases between successive pairs when going to the right. The final instrument used was the Wild A-7 Autograph.

The Wild A-7 used in the photogrammetry laboratory was calibrated prior to the test. It is equipped with a Wild EK-5 three-axis digitizer from which the model coordinates were recorded. The electrical connector to the instrument was modified by including a hand switch that turned off both the lighting of the instrument and a timer so that the investigator could record the time required to make the measurement. The test involved the placement of the floating mark on a predefined point within the stereomodel. Ten settings constituted a group with seven groups observed over an hour time interval for the testing. The observations were timed and speed was important, but the individuals were told that accuracy in placing the floating mark on the ground was the most important aspect of the stereoplotter test. It was also necessary to bring the floating mark down to the point from a higher position. While the lighting was turned off, the Z-carriage was moved.

Each of the individuals in the experimental group then undertook a seven week vision training program. The schedule is shown in Table 1. The program consisted of one hour of supervised training and an additional hour of unsupervised training each week. This training program was general in nature since it utilized common, ordinary procedures. So as not to taint the results, the experimental group did not perform any stereoplotter assignments that would aid the individual in their stereo performance on the plotter. After the vision training was completed, each person within both the control and experimental groups underwent testing again on the Howard-Dolman apparatus, Keystone Multi-Stereo test, and the stereoplotter.

	Supervised	*Unsupervised*
Week 1	Monocular Rotations Tachistoscopic Presentation	Near-Far Accommodation Pursuit Training
Week 2	Tachistoscopic with Prism Cheiroscope (large figure)	Brock String Diplopia Brock String Convergence ±2.00 Lens Flip Accommodation
Week 3	Haidinger Brush Fixation TV Anaglyphic Anti-Suppression	Cheiroscope (small figure) ±2.00 Lens Flip Accommodation
Week 4	Binocular Rotations with Prism Stereoscope Jump Convergence	TV Anaglyphic Anti-Suppression Cheiroscope (small figure)
Week 5	Polachrome Orthoptor ±2.00 Lens Flip Aperture Rule Trainer	Stereoscope (AN Series)
Week 6	Polachrome Orthoptor ±2.00 Lens Flip	Polachrome Orthoptor
Week 7	Stereoscope (AN Series) Polachrome Orthoptor Aperture Rule Trainer	Polachrome Orthoptor

Table 1. Initial training schedule for the vision training experiment [from Saladin and Rick, 1982a, p.385].

The results, presented by Saladin and Rick [1982a] are summarized as follows. Two statistical tests were performed on the results: the Wilcoxon Signed Ranks Test and the Student's t test. Both procedures require pairings to be made for the establishment of dependence. As explained by Saladin and Rick, the Wilcoxon test "assumes no distribution (is non-parametric) and recognizes the difference between the acuity gain attained by the experimental subjects but does not give overdue importance to the amount of difference". On the otherhand, the Student's t test for the difference between two dependent means "assumes a normal distribution of the data and recognizes not only the rank order of the data, but also the amount of the differences between the before and after training acuities".

From the data collected on the stereoplotter, the stereoscopic threshold change was found to be significant at the 0.05 level, using a one-tail test, for both the Wilcoxon and Student's t tests. Since the stereoplotter observations were timed, an attempt was made to measure both speed and fatigue. There is evidence that the experimental group did become faster in their observations after training but this hypothesis is not supported statistically. Likewise, the one hour testing on the stereoplotter did not show a definite trend in terms of fatigue. This would require a longer period to determine any effect. On the Howard-Dolman apparatus, the experimental group also showed improvement at the 0.07 significance level for both statistical tests. Finally, on the Keystone Multi-Stereo test, no differences were found between the control and experimental groups but this was due to the fact that this test is not as sensitive in the determination of stereoscopic acuity as the other two methods.

VISION TRAINING PROGRAM

From the results of the experimentation, it can be stated that the stereoscopic acuity of an individual can be improved through vision training. Thus, a refined training program was developed under a grant from the U.S. Defense Mapping Agency. This program is designed such that the individual plotter operator could develop a better than average stereoscopic acuity. It is flexible in that individualized training can be developed for the weaknesses of Category II personnel. Fry [1942] designed a standard for evaluating stereoscopic acuity. He defines the 100% acuity standard as an average value of the whole population in which the standard deviation on the Howard-Dolman test is 4-cm with a 6-meter testing distance. This corresponds to an angular value of 30 seconds of arc. But, Saladin and Rick [1980b] believe that 20 seconds would be a better standard for stereoplotter operators for two reasons. First, the Fry standard is based on a population in which the refractive errors and oculmotor imbalance were not carefully corrected. Secondly, because of the special stereoscopic abilities required of a plotter operator, it makes more sense that these individuals should have better than average visual capabilities.

The current training program developed by Saladin [1983] is divided into 8 weeks of training. Most tasks can be easily mastered, given a half hour of daily training, within 3 days. Since individual visual capabilities differ, some tasks may require additional training. The task and it's purpose, extracted from the Saladin manual, are shown in the Appendix.

The vision training program is a dynamic project and as additional data is collected, modifications to the program may develop. The Center for Photogrammetric Training and the College of Optometry are also investigating the creation of an instructional aid developed primarily for the contouring process. This ability is normally gained after considerable experience. The concept is to exploit the phychological funtions of vision by forcing the operator to "see" the correct contour line [Burtch, 1984].

CONCLUSION

The use of a vision training program has been presented and results indicate that the stereoscopic acuity of the plotter operator can be improved through it's utilization. It has also been shown that it is essential to categorize individuals in order to determine their visual capabilities and by doing so, one can identify employees who exhibit vision handicaps that, if left uncorrected, could affect the accuracy of the photogrammetric product. It also identifies persons who have handicaps that cannot be corrected and should not be given tasks that require vision capabilities that they do not possess.

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APPENDIX

Present outline of the vision training program.

WEEK	TASK	PURPOSE
1	Pursuit	To assure that the visual system has the basic ability to follow a moving object.
	Saccadic Fixation	To develop the ability for accurate fixation upon moving targets with either eye under binocular conditions.
	Fine Fixation	To teach a person to hold fixation on a small point using the most spatially sensitive portion of his retina.
	Monocular Accommodation (near-far)	To train the visual system to accurately and quickly adjust it's focus between near and distant objects.
2	Tachistoscopic Presentation	To decrease visual processing time and therefore to increase the speed of visual discrimination.
	Convergence Training	To enable the individual to maintain comfortable fixation for near tasks. (two week task)
	Binocular Accommodation (near-far)	To exercise the focusing mechanism and the aiming mechanism for fast, easy adjustment between far and near tasks.
	Binocular Accommodation (+1.00 D.Lenses)	To learn to drive the accommodative (focussing) mechanism with blur only (two week task).
3	Positive Fusional Vergence	To develop the ability to converge the eyes for a nearer fixation distance while maintaining focus for a more distant fixation distance (two week task).
	Anti-Suppression Training	To reduce suppression which is caused when the brain has learned to ignore part of the image from one eye and to depend mainly on the image from the other eye (two week task).
4	Sensory Fusion	The purpose of sensory fusion training is to enhance the visual system's ability to synthesize one percept from the two retinal images - one from each eye (two week task).
5	Divergence Facility (base-in prism)	This exercise is designed to stimulate those mechanisms (disparity detectors) in the visual system which provide the innervational pattern appropriate for a divergence movement and, incidentally, also provide the signal interpreted as a stereoscopic perception of "farther away".

5	Stereoscopic Training	This exercise is to transfer the skills learned in real space to stereoscopic space (two week task).
6	Vertical Vergence Training	This exercise sharpens the ability to fuse vertically disparate images (two week task).
	Anaglyphic Vergence Training	This exercise acquaints the student with the anaglyphic principle and continues developing disparity vergence flexibility.
	Accommodation-Stereopsis Interaction Training	This exercise is meant to build flexibility into the visual system to meet situation where an instrument is not readily focusable for his or her eyes.
7	Stereoscopic Location	This general category involves two different tasks which are designed to develop skills similar to placing the floating mark on a surface of equal horizontal parallax.
	Accommodative Facility with Stereopsis	This exercise is designed to promote flexibility in the focusing mechanism while viewing a stereoscopic scene.
8	Vergence Facility with Stereopsis	This general category involves two exercises designed to promote the ability to maintain stereoscopic perception with large amounts of horizontal misalignment of the stereoscopic pair.
	Reversed Parallax Training	This task also involves two exercises which pit the stereopsis clue against the secondary clues to depth.