MYOPIA REDUCTION TRAINING WITH A COMPUTER-BASED BEHAVIORAL TECHNIQUE: A PRELIMINARY REPORT

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ABSTRACT

Vision training has been suggested as a means of teaching myopes to both interpret blur and relax their ciliary muscles secondary to accommodative spasms. Perceptual habits can be taught through behavioral techniques and culminate in improved acuity. This research indicates the amenability of Snellen letter recognition performance to training. Subjects were required to monocularly recognize computer-generated letters which were then adjusted larger or smaller commensurate with performance. Feedback was provided after each attempted recognition and review of errors encouraged. All seven subjects participating in five consecutive-day, one-hour training sessions exhibited acuity superior to their pre-training performances and six displayed post-training refractive condition reductions.

KEY WORDS

accommodation training, acuity enhancement, acuity training, amblyopia training, behavioral training, computer, myopia, Snellen acuity

There is evidence to suggest that unaided visual acuity is not an unalterable physiological process. Psychological processes allow some degree of pupil control, blur interpretation, accommodative flexibility, and other cognitive mediation of acuity. Acuity performance is often assessed by the ability to recognize distant singular black letters on a white background. As long as this procedure is used to screen pilot training candidates, commercial pilots, operators of automobiles, and baseball umpires, its amenability to training should be investigated. The goal of this project was to further investigate the trainability of acuity and to measure both acuity and associated refractive condition changes.

A primary source of United States Air Force pilot candidates is the Air Force Academy and, accordingly, one of its goals is to both recruit potential pilots and have graduates enter pilot training. This requires that academy cadets have good eyesight upon entrance as freshmen and that they maintain acuity during their four-year enrollment. Eighty-five percent of the 945-member class of 1989 entered with pilot-qualifying 20/20 visual acuity; however, only 59% demonstrated that acuity in their commissioning physicals. If the assessments of these candidates' acuities are not accurate, if they could have improved with a few hours' practice, some may have been and continue to be needlessly eliminated.

Since 1862, the Snellen chart with its rows of high-contrast solid black alphabet letters printed on a white background has been used to assess acuity. Typically presented at 20 feet, the examinee's resolving abilities are confirmed once they discern a predetermined percentage of letters of one size. The charts are still available but more often today are projected on walls or displayed on computer screens. The ease with which these high-contrast acuity tests can be administered and their general public acceptance as an understandable and adequate vision metric has led to their widespread use as a model procedure for myopia assessment. But is such assessment amenable to or alterable with training?

Ricci and Collins[1] justified their training of myopes by reevaluating the nearsighted malady and conceptualizing myopia in behavioral terms. Birnbaum[2] suggested vision training as a regimen for the clinical management of myopia to facilitate development of adequate accommodative skills and freedom of action between the systems of accommodation and convergence.

The suggestion that an individual's behavioral style is a factor in the development of myopia is not new. Optometrists have observed patients who perform far better in the real world than their clinically assessed acuity would allow. Bates[3] and many of his followers (Peppard,[4] Huxley,[5] Corbett[6]) claimed improvements in the visual acuity of patients after training. The contribution that psychology might make to the understanding of myopia led Lanyon and Giddings[7] to state: "Whatever the precise mechanism of myopia turns out to be, it seems clear that it will be aptly described as a behavioral-physiological disorder, and that research of a psychological nature will play an increasingly important part in its understanding and prevention." (p.280)

Researchers have tried to pinpoint the components facilitating acuity enhancement. Trachtman[8] found that a reduction in pupil size alone may improve acuity although accommodation remains unchanged. It has been suggested that one benefit of vision training might be a heightened subjective sensitivity to blur. The resultant superior blur interpretation may be attributed to a more practiced blur-accommodation loop.[9] Giddings and Lanyon[10] examined the role of relaxation in perceptual performance and found evidence for a trend toward an increase in refractive error among "stressed" myopes. Several investigators have demonstrated the presence of voluntary accommodation in a variety of tasks.[11,12,13,14] Roscoe and Couchman[15] found that subjects displayed improvements in their visual acuities by exercising acquired control over volitional accommodation.

Relatively few optometrists or ophthalmologists have reported clinical reduction of myopia as a result of training programs.[16,17,18] In Woods' study,[19] 60% of the myopes showed significant acuity improvement through training, with no reduction in clinically-measured myopia. Gibson[20] proposed that trained subjects show an increase in acuity as a result of adaptation to the procedure or perceptual learning. Such negativity toward training has been based on an incomplete understanding of the physiological and psychological mechanisms involved in acuity enhancement. Harmon[21] suggested that the classical view of vision leads clinicians to a static perspective in which there are only slight variations between physics-based optics and human-eye optics. He proposed that total visual performance depends not only on the "bench optics" perspective but also on the perceptual system and accommodative mechanism. "For the eye has every possible defect that can be found in an optical instrument, and even some which are peculiar to itself."(p.14)

Some investigators have found both subjectively reported qualitative and significant quantitative improvements as a result of vision training. Giddings and Lanyon[22] found significant increases in acuity with accompanying decreases in refractive error. The improvements occurred in subjects receiving training with contingent approval. They reported an average of 0.25 D less myopia in subjects who participated in visual acuity training. Randle[23] taught volitional focus control to myopic subjects, who subsequently showed an average acuity improvement from about 20/75 to 20/50. Berens et al.[16] achieved significant acuity improvement and refractive error reduction. However, all subjects assigned to the treatment group were judged "highly motivated" and those assigned to the control group were judged "poorly motivated."

Motivation, pre-training abilities, and reinforcement have been cited as critical components in previous visual acuity training. Birnbaum[2] noted that visual acuity training commonly resulted in unaided acuity changes for myopes when motivation was high. Owens[24] found subjects could identify gratings of lesser contrast if they exerted effort. Likewise, Margach (cited by Friedman)[25] found accommodative response linked to the cognitive act of trying to identify visual objects. Just "thinking near" or "thinking far" has been proven to influence the rapidity of the drift toward resting state empty field myopia.[26] In addition to motivation, pre-training acuity likely influences those who will benefit most rapidly from vision training. Berman et al.[27] claimed that persons with the most impairment exhibit more rapid increases in acuity enhancement. As early as 1948, Sloane, Dunphy and Iannsons[28] advised their fellow vision training colleagues that if one is interested in selecting those patients most likely to benefit from training, "The best results may be anticipated in a patient whose visual acuity is found to be less than one would expect from a determination of his refractive error."(p.112) Reinforcement in acuity training has also proven to contribute to improvement.[29]

Giddings and Lanyon[22] exposed subjects to visual stimuli that were made progressively smaller, a process they called "fading." Subjects given "praise" contingent upon correct identification were able to identify smaller targets after the training. If they received non-contingent feedback or no praise, they showed less improvement. Epstein, Collins, Hannay, and Looney[30] modified the fading to entail moving stimuli farther away and renamed the contingent praise "feedback." In subsequent investigations, Collins, Epstein and Hannay[31] found those trained with fading and feedback exhibited significantly more visual acuity improvement than matched control subjects. Leber[32] trained his subjects for five consecutive-day, one-hour sessions. He found that subjects trained with performance-contingent fading and feedback displayed the most improvement on stimuli used in training as well as on many acuity assessment stimuli not used in training.

Some people who seek training in their visual performance or, specifically, improvement in their clinically chart-assessed acuity are motivated to improve their vision for a particular purpose. It may be to allow them to attend a service academy, commence an employment training program, obtain or maintain a flying certification, enter police or fire department training, or shed lenses they might otherwise be required to wear but find uncomfortable, unattractive, or hard to wear under certain circumstances. People with these goals probably do not need as much encouragement, reinforcement, or extrinsic motivation as others who have similar vision decrements but who lack an intrinsic desire of equal strength. Air Force Academy cadets are highly motivated subjects. Their entrance into pilot training upon graduation requires they attain at least 20/70 Snellen letter acuity at distance without correction and 20/20 acuity at distance with correction. It would be very difficult to find more motivated, dedicated, or willing subjects.

In a previous project, one of the authors, Dr. Leber, trained both college freshmen and Air Force Academy cadets with letters and Tumbling E targets made progressively smaller or larger commensurate with recognition accuracy. The letters were displayed on a Macintosh Plus computer that was rolled on a wheeled platform toward or away from the subject. Eleven of 18 subjects performed better after training, four displaying pre-training/post-training acuity improvements of 20/70 to 20/40, 20/50 to 20/40, and 20/40 to 20/25, 20/30 to 20/20. But these improvements were not substantiated by a diminution of myopia. Consequently, any improvement might have been solely the product of enhanced blur interpretation. The present project was to determine if the same type of training could produce optometrist-confirmed acuity performance enhancement and with reductions in myopia.

METHOD

An acuity training program was written that would operate on the IBM-compatible computers issued to every cadet at the Academy. This copyrighted software displayed 24 letters of the alphabet, as shown in Figures 1 and 2, at sizes ranging from 20/12 to 20/120 when viewed from 20 feet. Limited letter sets of any size could be selected for particularly difficult letters; e.g., O, C, and D as in Figure 3. Four letters appeared on each screen of 20/70 or smaller, while only three 20/71 or larger letters were displayed at a time. Subjects responded with keyboard inputs to each series of letters. If any responses were incorrect, a beep sounded and the correct letter was displayed one-third larger above its smaller self, as shown in Figure 4. If all four or all three letters were correctly identified, the next display was adjusted to one gradation smaller, e.g., perfect 20/70 recognition was followed with a display of four 20/69 targets. If one letter was incorrect, the next display was unchanged in size. If more than one was incorrectly recognized, the next display was one gradation larger. Although training could be accomplished at any distance, if viewed at 20 feet the small numbers in the corner of the screen indicated the Snellen chart equivalent size of the targets.

Seven male subjects, ages 19 to 23, were trained with this acuity training software and regimen. They were volunteers and received no compensation for their participation. All were initially screened by the optometry clinic for monocular acuities and refractive condition. Each was trained for five consecutive-day one-hour training sessions. Six sat 20 feet from the computer screen and one sat 10 feet away because his pre-training acuity was worse than 20/120. A notecard was held in front of one eye while the other was individually trained. After every 15 to 20 displays the notecard was moved to the other eye.

The assessment and training room was completely dark except for the light from the screen. The trainer (Dr. Leber) sat next to the computer and transposed subjects' verbal responses into keyboard letter entries. Initial training was with letters commensurate with their optometrist-rated acuity. Successive training sessions began with letters of the same size as those displayed at the termination of the previous day's training. When subjects experienced difficulties with certain combinations of letters, the trainer programmed the software to display only those letters. The most common confusable combinations were -O, C, D; -H, N, M; -T, Y, U, V; and -E, B, F, P.

Figure 1. Four 20/30 acuity letters when viewed from 20 feet.

Figure 2. Four 20/40 acuity letters when viewed from 20 feet.

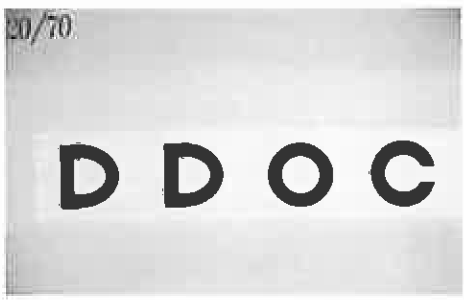

Figure 3. Four 20/70 acuity O, C, and D limited letter set display.

Figure 4. Three 20/100 acuity letters after an incorrect observer response for the third letter.

No squinting was allowed. Only passive vision was permitted and any wrinkling of the forehead or head movement was not allowed. Many subjects regularly blinked prior to attempting recognition, resting for three to five seconds, and then passively opening their eye and reporting the letters on the screen.

The visual acuities of four control subjects were measured twice, with 96 hours of separation between assessments. These acuity measurements served as comparisons to days one and five of the trained subjects. The initial acuities of the control subjects were nearly identical to four of the experimental group subjects.

RESULTS

All seven trained subjects displayed optometrist-confirmed acuity performance improvement in at least one eye, three in both eyes. Six of seven had confirmed myopia diminutuin of 0.25 D in one eye, two had improvement in both eyes. Pre-training and post-training acuities and measured myopia are shown in Table 1. Only one of the four control subjects displayed a change in acuity, one eye improving from 20/100 to 20/80 as shown in Table 2.

Performance regression from one day to the next was nearly nonexistent. In a previous study,[32] six subjects were trained with similar letters and Tumbling E computer-displayed targets. Their daily regression was likewise minimal and 45 days after their last day of training five had retained all of their improvement with no interim training. Only one subject's performance regressed slightly after 45 days, but still remained superior to his pre-training acuity.

Subjects were anxious to train and reacted positively when their accurate performance drove the letters smaller and smaller. Occasionally, they would have difficulty with a particular letter set, often

TABLE 1.
PRE-TRAINING AND POST-TRAINING ACUITIES AND MYOPIA AMOUNTS OF EXPERIMENTAL SUBJECTS.

		TRAINED SUBJECTS			
		ACUITY		MYOPIA AMOUNT	
		PreTng	PostTng	PreTng	PostTng
Subject #1	Right	20/25	20/20*	-0.25	-0.25
	Left	20/20	20/20	-0.50	-0.25*
Subject #2	Right	20/25	20/20*	-0.50	-0.50
	Left	20/30	20/25*	-0.75	-0.50*
Subject #3	Right	20/40	20/30*	-0.50	-0.50
	Left	20/50	20/50	-1.00	-0.75*
Subject #4	Right	20/70	20/70	-1.50	-1.25*
	Left	20/100	20/70*	-1.50	-1.25*
Subject #5	Right	20/80	20/80	-1.50	-1.50
	Left	20/50	20/30*	-0.75	-0.75
Subject #6	Right	20/100	20/80*	-1.50	-1.25*
	Left	20/100	20/80*	-1.50	-1.25*
Subject #7	Right	20/250	20/200*	-3.25	-3.25
	Left	20/250	20/200*	-3.50	-3.25*

*Denotes Training Enhancement

TABLE 2.
PRE-TRAINING AND POST-TRAINING ACUITIES OF CONTROL SUBJECTS.

		CONTROL SUBJECTS ACUITY	
		PreTng	PostTng
Subject A	Right	20/25	20/25
	Left	20/25	20/25
Subject B	Right	20/50	20/50
	Left	20/50	20/50
Subject C	Right	20/70	20/70
	Left	20/70	20/70
Subject D	Right	20/100	20/80*
	Left	20/100	20/100

*Denotes Training Enhancement

O's, C's and D's or T's, Y's and V's. Training with these limited confusable sets invariably resulted in improved recognition, changes of five to 10 graduations with only five-minutes' training. The improvement regularly transferred to the full 24-letter set after only a few more minutes of training.

Subjects were asked if there was any discomfort experienced as a result of the training and only watering of the eyes was regularly reported. One subject had a headache at the conclusion of training on one day but it went away soon after the session and did not reappear during subsequent sessions. Watering of the eyes and fatigue lessened from day to day. Fatigue was reported by many subjects the first day after only 15 to 20 minutes of training, but by the fifth day was either nonexistent or manifest after 40 to 50 minutes.

DISCUSSION

Improved visual acuity was achieved using behavioral training techniques. This adds credence to Fenton's[33] hypothesis that the improvements in acuity are the result of both an increased ability to discriminate distant blurred stimuli and by refractive error enhancements, making distant stimuli more clear. After five consecutive-day, one-hour training sessions, subjects trained with performance-contingent fading and feedback displayed consistent improvement in Snellen letter recognition performance. The combined influence of physiological changes, modified processing, and motivation achieved through simple practice with this software improved visual acuity in myopic subjects.

Only one subject was trained more than five hours. Subject six, displaying pre-training 20/100 distant acuity in both eyes, recognized 20/80 letters after five hours of training and 20/50 letters after another five hours' training. This suggests that five hours of training may not be enough for some subjects to realize maximal distant acuity performance enhancement.

The subjects in this experiment were excited about their participation and improvements. They were anxious to train and showed obvious signs of gratification after nearly every training session. It was the feedback and constant challenge that kept admittedly motivated subjects focused on their goal of acuity performance enhancement. No promises of improvement were made nor was the training promoted as a means to guarantee acuity improvement. Although Academy graduates have routinely been allowed to commence pilot training with uncorrected monocular acuity as low as 20/70, none of the subjects were encouraged to feel they were assured of reaching pilot qualification.

Since this training was started at the Academy, dozens of cadets have approached Dr. Leber with desires to participate. He has given and will continue to give cadets who inquire about the training a copy of the software. If he cannot have time to personally train them, three pages explaining how to conduct the training themselves is provided. Dr. Leber has formed a company and markets the software commercially at $59 a copy through Acuity Performance Training Company, Box 1318, Monument, CO 80132. The software has already been purchased by prospective pilot training candidates and airline pilot applicants.

The small but consistent improvement displayed by the seven participants in this pilot project suggests that a computer-based behavioral technique may be a viable training technique for improving unaided distant acuity performance. This software may be a good tool for optometrists who provide myopia reduction training and who wish to provide patients with an inexpensive home training device. In addition, amblyopic patients may benefit from this technique. This study suggests that training can improve distant acuity performance and produce slight refractive error reduction.

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