Correcting Intermittent Central Suppression Improves Binocular Marksmanship

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Intermittent central suppression (ICS) is a defect in normal binocular (two-eyed) vision that causes confusion in visual detail. ICS is a repetitive intermittent loss of visual sensation in the central area of vision. As the central vision of either eye "turns on and off," aiming errors in sight can occur that must be corrected when both eyes are seeing again. Any aiming errors in sight might be expected to interfere with marksmanship during two-eyed seeing. We compared monocular (one-eyed, patched) and binocular (two-eyed) marksmanship with pistol shooting with an Army ROTC cadet before and after successful therapy for diagnosed ICS. Pretreatment, monocular marksmanship was significantly better than binocular marksmanship, suggesting defective binocularity reduced accuracy. After treatment for ICS, binocular and monocular marksmanship were essentially the same. Results confirmed predictions that with increased visual stability from correcting the suppression, binocular and monocular marksmanship accuracies should merge.

Introduction

Do two eyes have any intrinsic advantage over one eye for combat marksmanship? Intuitively, having two eyes work together (binocularity) seems beneficial. More sensory information is available to the brain for decision making and the panorama provided by unimpaired peripheral vision for scanning and target acquisition is broader than that available with an eyelid closed.[1] Depth perception is often improved. In a combat situation, the additional sensory information should be helpful. Perhaps more meaningful to that combat situation, two eyes might be forced into simultaneous use over possibly using one eye alone (monocularity) by a sufficiently intense state of affairs.

In a suddenly intense combat situation—a "panic" situation—the sympathetic nervous system comes into play. Stimulation of the sympathetic nervous system increases heart rate and force to increase blood flow, relaxes the smooth muscle of the bronchi to increase airflow along with other beneficial "fight or flight" effects. Among these other beneficial effects, the sympathetic nervous system causes the upper eyelids to elevate. Therefore, both eyes are forced by the situation (and the sympathetic nervous system) to be wide open.[2] If this same suddenly intense combat situation requires marksmanship, both eyes are likely to be involved, even if monocularity were the preferred method of aiming a weapon.

Definitions

This case study ignores the standard and most frequently addressed visual issues of nearsightedness (myopia), farsightedness (hyperopia), and astigmatism. Those certainly can affect marksmanship if the shooter is unable to make the pistol site clear. But, binocularity is the concern of this study, not optical clarity as such.

Probably the most easily identified defect in binocularity is strabismus—an eye turn. Often associated with strabismus is amblyopia—lazy eye. In both these conditions, the central vision of the turned eye is almost completely shut off—suppressed. Peripheral vision remains intact and contributes to the panorama of sight. Measured depth perception (stereopsis) suffers.[3] Vision in these conditions, although different than good binocular vision, is stable, typically not changing with different demands.

Suppression is not a black out, but a loss of visual sensation. Suppressed areas of sight may be filled in perceptually by the same mechanism that fills in our natural blind spots.[4] The natural blind spot does not produce a constant black spot (a positive scotoma) in our peripheral vision. But, a sharp observer can find a "vacant" spot in the peripheral vision with the tip of a finger.

Marksmanship in strabismus or amblyopia (sighting with the dominant eye) would be similar to marksmanship with one eye closed or patched. Strabismus and amblyopia in this sense act like monocularity (one eye alone), not like two eyes working together (binocularity).

What if, rather than monocularity (strabismus) or true eyes-teamed-together binocularity, a marksman instead has defective or imperfect binocularity: two straight eyes incapable of precise sensory coordination? Intermittent central suppression (ICS) is such a condition, a defect in binocularity.[5]

"Intermittent" suggests one of the major differences between ICS and strabismic suppression: an ICS suppression is an "on and off" suppression. "Central" refers to the central area of sight, i.e., not the peripheral vision. Therefore, ICS is defined as a repetitive intermittent loss of central visual sensation in the absence of an eye turn (strabismus) or amblyopia (classic lazy eye). ICS alternates eyes in 80 to 90% of ICS patients.[5,6]

ICS suppression periods average 2 to 3 seconds in length and repeat at a rate typically producing two or three suppressions in a given 10-second period.[5,6] During the suppression period, the fixation lock for accurate aim of the suppressed eye is gone centrally, probably allowing some drift in eye aiming. Then, after the few-seconds-long suppression period, sensation returns. However, the formerly suppressed eye is now not precisely aligned with the fellow eye. In some patients, the suppression will alternate directly to the fellow eye. Often, both eyes will see simultaneously for a 2- to 3-second period before either eye is again suppressed. In either case, any aiming error must be corrected. Since ICS is repetitive, ICS patients suffer ongoing visual confusion from inaccurately superimposed images as well as moving images during corrective vergence eye movements. Note that although the visual confusion from ICS can be interpreted by some patients as blur, ICS is not related to decreased visual acuity from refractive errors.[5]

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I have suggested ICS is a neurological defect–specifically, a deficiency in the visual motion-sensing (magnocellular) pathway at the level of the lateral geniculate nucleus, the vision relay station halfway from the eye to the brain. A deficiency in the visual motion pathway reduces the signal that keeps the visual detail (parvocellular) pathway operational. Detail then fades. The motion-carrying magnocellular pathway is the "on switch" for the detail-carrying parvocellular pathway.[7,8]

This visual pathway theory of ICS is at odds with the conventional wisdom on suppression. The conventional wisdom, derived from strabismus and amblyopia, defines all suppressions as cortical competitive inhibitions. Visual signals at the cortex either "fight or fuse."[9] The cortical theory provides no explanation for the intermittency or alternation of ICS, characteristics of ICS that can be explained more easily and more thoroughly by the visual pathway theory.[7,8]

If we have described this condition correctly, we would expect some interference in binocular marksmanship in an ICS sufferer. Furthermore, we would expect an improvement in marksmanship under monocular conditions. One way to improve marksmanship in an ICS sufferer, then, might be to give that shooter a patch or teach him to close an eye when shooting. Perhaps attention could be trained to enhance concentration on one eye's image relative to the other. But, these compensations are all open to our original criticism of monocularity in a suddenly intense combat situation.

The other way to deal with defective binocularity (ICS) and its effect on marksmanship would be to treat the suppression. If the suppression of ICS could be substantially reduced or eliminated, the increased sensory stability should produce a merging of accuracies in monocular and binocular marksmanship conditions. This case study will look at pistol marksmanship before and after correcting ICS.

Case Report

J.P. was a 21-year-old male Army ROTC cadet. We treated J.P. for ICS during the second half of his junior year in college. By that time he had accomplished the typical ROTC rifle training but was a relative novice with pistols.

At the pretherapy examination in November 2004, J.P. saw a normal 20/20 at distance with either eye, required no distance lenses, and had no strabismus or eye pathology. Reading glasses predictably had not eliminated the suppression. If we hold to the motion pathway theory of ICS, there is no neurological reason lenses would improve ICS in more than a transient fashion. He showed fairly typical alternating ICS pretherapy, although J.P.'s left eye suppressed much more often than his right. He is right-handed and right-eyed.

Methods

J.P. shot with identical 9-mm pistols at an indoor target shooting range before and after therapy for ICS. Both marksmanship test sessions used five standard "bull's-eye" marksmanship targets set in succession at 25 feet. Each individual test condition used a clip of 10 rounds. In both sessions, the first target was used as a warm-up practice target. Thereafter, the four targets were used with successive 10-round clips alternating between the two test conditions.

Test condition 1 was the monocular condition. J.P.'s nondominant eye was patched and 10 rounds were fired at the target. Test condition 2 was the binocular condition. Both eyes were held open. J.P. was instructed to aim to the best of his ability based on where he saw the target. In both test conditions, J.P. fired one round every fourth second. A timer counted out seconds on a digital watch to each shot: "one . . . two . . . three . . . fire" until each round in the clip had been fired. This was our method to randomize J.P.'s aiming relative to any visual changes from the ICS: he was required to squeeze the trigger on command whether in a suppression period, an eye-aiming correction period, a truly binocular period, or patched.

Test conditions 1 and 2 were repeated with fresh targets for a total of four test shot targets and 40 rounds. The four test-condition targets at both test sessions were then measured for lateral inaccuracies from target center. Here, we assumed vertical errors would more likely be a function of practice and technique than of the eye condition and the theorized visual changes from the ICS. The entire procedure was repeated 6 months later after the suppression had been almost eliminated (estimated 95+% improved). J.P. was instructed to do no pistol shooting nor receive any pistol instruction between the two test sessions unless required by his ROTC. He confirmed that he received no such pistol experience in the interim.

Therapy

We used both traditional antisuppression therapy procedures such as stereoscope-drawing procedures and diplopic (double vision) eye movement procedures, and more recent and more forceful electronic rapid alternate occlusion procedures.[10] Breaking these antisuppression therapies down to their stimulus-level functions shows the two components of any antisuppression procedure: bilateral sight with a motion stimulus. Electronic rapid alternate occlusion delivers a strong bilateral motion stimulus using liquid crystal shutter lenses to create visual flicker—motion in stimulus form.[11] Direct alternation between the eyes at (typically, approximately) 5 Hz is fast enough that the central vision reads the signal as continuous, i.e., bilateral. Apparently paradoxically then, electronic rapid alternate occlusion delivers a strong bilateral motion stimulus, strong enough for antisuppression therapy.[10,12]

Therapy was carried out on an in-office basis. Twenty-six in-office therapy sessions were carried out over 22 weeks. Total in-office therapy time was approximately 18.5 hours. As a matter of course in vision therapy procedures, some accommodative (focus) training, convergence (eye aiming) training, and eye movement training will occur, but the target of therapy was always to eliminate the ICS.

Marksmanship Results

For the purposes of these results, "binocular" refers to both eyes being open, i.e., the nonpatched condition. "Monocular" refers to the patched condition, that is, only the dominant eye being used. Accuracy averages are expressed in centimeters away from the target center measured laterally.

The results show that J.P. did not improve his marksmanship outside of our study during the pretherapy-post-therapy interim. In fact, his monocular (patched) marksmanship was 5% less accurate at the second session than at the initial shooting session. Although 5% less accurate is insignificant, it does suggest there was no intervening pistol practice.

Pretherapy binocular and monocular conditions showed very different accuracies. The monocular condition was 49% more accurate than the binocular: 3.86 versus 7.62 cm away from center. One SD from the monocular mean does not include the binocular mean; therefore, these are very different accuracies. The two SDs give a picture of how erratic aim was: the binocular condition aim was 34% more variable than the monocular. Therefore, as we might suspect from the description of ICS as a visual confusion-producing condition, J.P. was less accurate and more variable (or more erratic) in aim when both eyes were used (the binocular condition).

Post-therapy binocular and monocular conditions are not different. The binocular condition (both eyes, unpatched) was actually slightly more accurate (5%; 5.24 cm versus 5.54 cm) than the monocular condition. Both means are well within each other's SDs. Compared to pretherapy patched/unpatched accuracies, this is a very different finding. In addition, post-therapy binocular aim is much less variable than pretherapy binocular aim. Both binocular conditions are more variable than the monocular conditions, but post-therapy, the binocular aim is 15% more variable than the monocular rather than the pretherapy 34% more variable. The decrease in variability post-therapy seems even more impressive when the variability in monocular aim is taken into consideration: post-therapy monocular aim was 5% more variable than pretherapy. J.P. just had a less accurate and more variable day at the second session, again speaking to his lack of pistol or "aiming" training during the pretherapy to post-therapy interim as well as adding emphasis to any post-therapy improvements. The post-therapy binocular condition is 31% more accurate than the pretherapy even with the overall less accurate second session. These changes are summarized in Figure 1.

ICS Results

ICS diagnosis is made during a routine optometric analytical examination using vectographic binocular refraction targets presented at standard distance (20 feet) and near (40 cm) test distances.[13] Vectographic targets use polarization to provide for separation of the two eyes' central fields in a visual test environment that, although not perfect, is relatively normal in its perception. By appropriate questioning in that test environment, suppressions will be reported as targets "disappearing and reappearing" or on targets assembled with overlaying polarizers as targets "blacking out."

The pretherapy diagnostic examination was in November 2004. Therapy was concluded in May 2005. At that time, I estimated the ICS as 95+% improved. For that estimate, I compared suppression responses on vectographic targets from examination to examination. Therefore, from a more typical 2- to 3-second on/off cycle ICS, J.P.'s suppressions were now very short-duration losses of sensation, well under 1 second ("a blink"), happening every 5 to 7 seconds. Zeri et al.[14] have devised a different suppression classification system. In their system, typical ICS would rate as S4, no suppression would be S0 (zero). J.P., then, changed from Zeri S4 to S2. Not perfect, but near normal, and certainly greatly improved. In addition, distance stereopsis (measured depth perception) improved to a reliable maximum (for this test) of 88%. We can speculate about possible

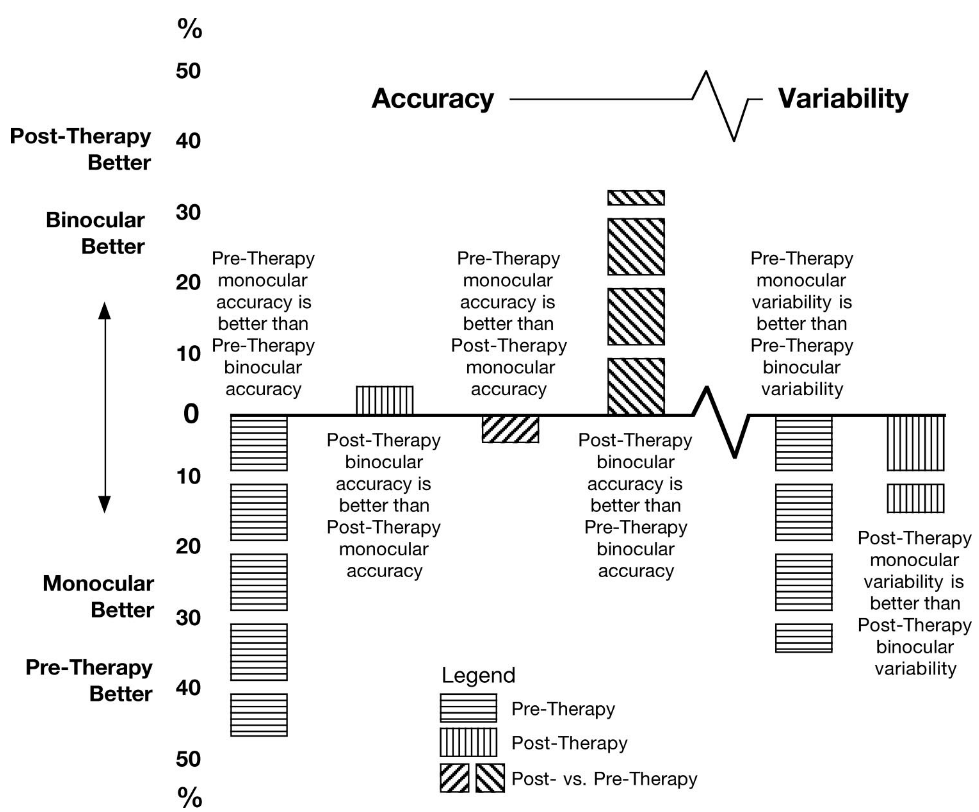

Fig. 1. Summary of monocular-binocular and pretherapy-post-therapy data.

positive effects of reliable distance depth perception for (for example) various airborne activities.

Discussion

A first point concerning binocularity is that ICS can be treated effectively with current therapies. Less than 20 total hours of therapy improved J.P.'s suppression from a typical 2-or-so seconds "off," 3-or-so seconds "on" repetitive suppression by at least 95% (Zeri S4–S2). The suppressions have been reduced to significantly shorter "off" periods, therefore providing significantly more binocular visual "on" time. Although accommodation (focus) and convergence (aim) were also treated to some extent as a byproduct of the suppression therapies, there was relatively less change in those functions. The major changes were in the suppression, treated with traditional vision therapies and with electronic rapid alternate occlusion.[10,12] A potential advantage of electronic rapid alternate occlusion is that it may be effective as a stand-alone therapy for ICS and therefore useful in locations remote from traditional clinics.[15]

A second point concerns binocularity and marksmanship: pretherapy, "binocularity" interfered with accuracy. More accurately, defective binocularity interfered with accuracy when both eyes were open. Pretherapy, this is a soldier who would benefit from instruction to shoot a pistol monocularly. In emergency situations, the role of defective binocularity would need to be understood and compensations would need to be devised that could be chosen by the soldier "automatically." Obviously, training can help this soldier's chances of survival, but only with appropriate understanding and compensations.

Post-therapy, this is a soldier who can function in either monocular or binocular emergency situations. Binocular accuracy is now the same as monocular accuracy. That means fewer compensations need to be devised to protect this soldier in a variety of combat and emergency situations. His survivability has improved.

A third point is that variability in aim has improved post-therapy. Binocular aim is still more variable than monocular, but less so than pretherapy, improving from 34 to 14% more variable than monocular aim.

After treating the ICS, binocular and monocular aiming are now much the same. The ICS is no longer interfering with marksmanship. Suddenly, intense combat conditions present one less worry with this soldier: marksmanship will not suffer from defective binocularity as the sympathetic nervous system drives both eyes wide open.

Conclusions

This is the first case study diagnosing and treating ICS while measuring marksmanship. Larger studies have not been done. But, this case study does fairly precisely support our original contentions that in an untreated ICS patient monocular marksmanship should be significantly better than binocular marksmanship and that, in correcting the ICS, we should see a merging of monocular and binocular marksmanship as the fixation variability of defective binocularity no longer interferes with aim.

This suggests some directions for future research: if we look at two groups, one with diagnosed ICS and one without ICS (having been fully tested for ICS), will we see the same difference between binocular and monocular marksmanship? If so, can we treat the ICS efficiently in a large group? Since ICS has been associated with reading problems,[5–8,13,15] will we see other effects of treatment of the ICS? We might speculate that areas of training that are reading-intensive would become easier for a treatment group.

Final questions are practical questions: can military optometrists modify their test procedures to screen for this visual defect? Can screening diagnoses be made by training officers? Is it economically feasible? On the economics, the Army will have invested well over $100,000 in J.P. by the time he graduates from college. In that context, both the monetary cost and the 20 hours of time investment (probably longer on tougher cases) seem minimal. An ongoing pilot study is looking at the questions of feasibility of remote treatment and effects on reading ([16]).

Acknowledgment

Dr. E. S. Hussey is the primary inventor of the electronic rapid alternate occlusion goggles mentioned in the "Therapy" section. No commercial version is yet available. Clinical studies continue.

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