Major Review:

Intermittent Exotropia
Basic and Divergence Excess Type

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Major Review: Intermittent Exotropia
Basic and Divergence Excess Type

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ABSTRACT: Intermittent exotropia is a unique strabismus with a specific set of sensory motor findings. This paper provides a comprehensive review of nomenclature, epidemiology, sensory motor findings, theories of etiology, and treatment of intermittent exotropia, of both basic and divergence excess types.

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I. NOMENCLATURE and INCIDENCE

A. Nomenclature

Intermittent exotropia (X(T)) is a unique strabismus with a specific set of sensory motor findings (1).

Duane originally, in 1897, used the term divergence excess to describe almost all exodeviations especially those with a deviation larger at distance than near (2).

According to Duane, these exodeviations were a result of active divergence and their sensory motor findings were uniquely different from those found with convergence insufficiency type exodeviations. Conversely, Knapp (3), Wilsdon (4), and Jampolsky (5) have all felt that since the distance exodeviation was not a result of active divergence, a more appropriate term should have been simply intermittent exotropia.

Various other descriptive terms have been used to identify this entity. Each has been an attempt to describe the condition by its major characteristic. They include Pugh's "occasional exotropia" (6), Wortz's "neurogenic exotropia" (7), Bleck's "periodic exotropia" (8), Sugar's "hyperkinesis of divergence" (9), and Burian's "exotropia of inattention" (10). The current descriptive term is divergence excess intermittent exotropia, abbreviated DEX(T).

 Patients with DEX(T) typically have intermittent deviations with infrequent reports of diplopia. Knapp (3) & Jampolsky (5) have used patient complaints of diplopia and/ or hemiocular suppression to differentiate exophoria from exotropia. However, this has only served to confuse the issue since some deviating DEX(T)s have diplopia at times, while others suppress or avoid diplopia with abnormal retinal correspondence (ARC).

Dunnington (11) suggested DEX(T) should be defined by its major characteristics. He reported seven chief characteristics which included marked exophoria for distance, excessive prism divergence, normal prism convergence, normal near balance, normal near point of convergence, normal rotations, and diplopia, if present, consistent to the left and right. Sugar (9) defined DE as "Exophoria or esotropia greater at distance than at near, good vision in each eye, suppression when manifested, fusion when increased and increased prism divergence for distance, particularly".

Costenbader (12) presented the most complete and clinically accurate description of the entity. His description included exophoria-exotropia at distance, normal near point of convergence, adequate prism convergence, intermittency, equal vision, good stereopsis, and ARC when exodeviated.

One can define any strabismic condition by its major motor characteristics, realizing that motor anomalies have commonly associated sensory motor findings. Thus, DEX(T) may be defined by both its spatial (distance/near relationship) and temporal (constant, intermittent or phoria) motor characteristics. Thus, the proper nomenclature might be intermittent exotropia of the divergence excess type (1).

Duane (2) also described another type of XT where the objective angle at distance and at near are equal. He stated that this exodeviation was a DEX(T) with an acquired secondary convergence insufficiency. Burian (10) labelled this third type of XT a basic XT (distance and near exodeviation are approximately equal).

Divergence excess and basic intermittent exotropes have similar sensory/motor findings and are probably variations of the same condition; thus, they are subsets of XT(T). These patients have an intermittent deviation which occurs from 1% to 99% of the time, have stereopsis when aligned, and suppression and/or ARC when tropic. Their sensory motor characteristics are different from those of constant exotropias, exophorias, or convergence insufficiency type X(T)s (13). (These latter types will not be discussed in this review.)

B. Incidence

Exotropia appears less frequently than esotropia (ET). The approximate ratio of XT to ET is 1:3 (14). Friedman et al (15) screened 38,000 children aged 1 to 2 years. They found 498 had a strabismus, of which approximately 25% were exotropic. Von Noorden (16) has suggested that XT is more prevalent in the Middle East, the Orient, and Africa. This observation supports the findings of Eustace et al (17) and observations of Romano (18) that XT appears more commonly in areas with greater sunlight.

Jenkins (19) reported that in a survey performed by the International Orthoptic Association 30% of all strabismus are exotropic. Japan and Nepal have the highest incidence of XT as compared to ET, i.e., 54% and 76%, respectively. This higher incidence of XT among Orientals/Asians as compared to Caucasians was noted previously by Ing & Pang (20). The prevalence of XT in Arabian countries, the United States, and United Kingdom are all similar, i.e., 30%.

C. Progression

Exotropia usually appears within the first few years of life and may progress. Von Noorden (21) followed 51 patients with XT who did not have surgery. He reported 75% showed signs of progression, 9% did not change, and 16% improved with time. Jampolsky (22,23) described DEX(T) as a progressive disease in which an exophoria, due to suppression, develops into an X(T) and finally a constant XT. Presbyopia results in a decrease in accommodation and an increase in both the frequency and size of the near deviation. These findings support Burian & Franceschetti's observation (24) that it is rare to find DEX(T) later in life. On the other hand, Hiles et al (25) followed 48 XT's for 6-22 years (average age 11.7) who had an initial deviation greater than 18° and who elected not to have surgery. Thirty-nine of 48 showed no increase in their exodeviations with time, 12 actually showed a decrease with time, and only 8 showed an increase which was less than 15°. Fifty-two percent actually had smaller exodeviations at the end of the study. The near point of convergence did not change with time. Hiles' study (25) "contradicted the general popular impression that all exophorias in childhood progress to constant exotropia in childhood". Friendly (36) has reported that Hiles et al used occlusion on some of the XT's, which they followed over time. Their findings might have been influenced by this.

Women clearly are affected more frequently by XT. Casse (27) reported that 70% of DEX(T) are women, while Krzywicka & Pajakowa found 67% to be female (28), and Gregersen 61% (29). Contrary to Donders (30), who reported a higher incidence of XT with myopia, most studies report a normal distribution of refractive errors with XT (31,32).

II. SENSORY-MOTOR FINDINGS

A. Motor Findings

1. Accommodative convergence / accommodation (AC/A) ratio

Divergence excess exotropia has by definition a larger distance deviation as compared to the near deviation. Duane (2) originally specified (arbitrarily) that the difference between the distance and near findings had to be at least 15°. However, most authors have adopted Burian's arbitrary difference of 10° between distance and near (10).

By this last definition, if one assumes a
normal average 60 mm (inter)pupillary distance (PD) and a 10\(^a\) difference between distance and near (40 cm), the distance near ACA has to be at least 10/1:

\[
\text{D/N ACA} = (PD \text{ cm} + \frac{\text{XT} - \text{XT}'}{D})
\]

\[
\frac{\text{D/N ACA}}{(6 \text{ cm} + \frac{10}{2.5})} = 10.
\]

Brown (33) reported that the mean distance near ACA in DEX(T) was 13/1. Similar findings have been reported by Jampolsky (34) and Parks (35). Basic XTs have similar near distance measurements, and thus are assumed to have normal ACA ratios, i.e., 6/1.

Clinical measurement of the distance/near ACA is confounded by various factors. It is often assumed that the accommodative response is the same as the stimulus to accommodation. For example, if a fixation target is placed at 40 cm a 2.5 D accommodative response is assumed. But the accommodative response is usually less than the accommodative stimulus at near and more at distance (36). Variability in distance/near ACA may also result from alterations in pupil size which is smaller at near, thus decreasing the demand for accommodation, the demand for an accommodative response and the resultant ACA. On the other hand, proximal convergence and vergence aftereffects (prism adaptation, slow vergence response) may increase the ACA (37) (See Section III C).

Though these factors at first glance may seem to be inconsequential, Oggle & Dyer (38), von Norden (39), Cooper et al (40), and Kushner (41) have all shown that stimulus-gradient ACA/As in DEX(T) patients are not excessively high but are only slightly above normal (range 3.0-9.0). Figure 1 (below) presents stimulus-gradient ACA ratios derived in a synoptophore and with a cover test. It is apparent that the gradient ACA/As in DEX(T), unlike normals, are not linear.

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Figure 1 (Cooper & Medow): Gradient stimulus ACA/As were determined in 3 subjects with a synoptophore and at near using alternate occlusion; i.e., alternate cover test. These patients had an average distance/near stimulus ACA of 11/1, and an average objective ACA of 5.9/1. Dashes represent repeat ACA/As 1 week later. It is readily apparent that the ACA is not linear nor exactly repeatable for DEX(T). The mean derived gradient stimulus ACA determined by a best fitting straight line was 5.0 in a synoptophore and 7.5 with cover test. (Original, unpublished data)
Ogle & Dyer (38) used fixation disparity methods to calculate stimulus AC/A. They reported an average AC/A of 3-4/1 in the DEX(T) (see Figure 2, right).

Interestingly, fixation disparity measured AC/A do not change significantly after surgery while distance near stimulus AC/A do. Cooper, Clauffreda & Kruger (40) simultaneously recorded accommodation and vergence responses using an infrared optometer and an infrared eye movement monitor. From their recordings they calculated response AC/A in both true and simulated DEX(T) patients. They found the response AC/A ratios to range from normal to slightly high. The mean response AC/A was 5.9/1 (with a range 4.5-8/1) (see Figure 3, top, next page >>>). Furthermore, they found no difference between response AC/A for simulated and true DEX(T). They postulated that proximal convergence in true DEX(T) and vergence aftereffects (slow vergence) in simulated DEX(T) were responsible for the discrepancy between distance/near AC/A ratios and gradient AC/A ratios in these patients.

2. Results from occlusion:

Any discussion of the effects of occlusion on X(T)s must address the concept of vergence aftereffect. Vergence aftereffects or slow vergence are a temporary change in oculomotor position which result from any sustained fusional induced vergence (42). For example, Ogle & Pragen (43) have shown that if 6 dipters of vertical prism is slowly added with a Risley prism, e.g., 1 dpt per minute, in front of some subject's eyes and those subjects completely adapt, both cover testing and forced fixation disparity curve before and while wearing the prism will be identical, e.g., orthophoria with and without the prism. Significant adaptation to the prism occurs within a few minutes. Abrupt removal of the prism usually results in diplopia with a slow recovery of fusion. The rate of recovery depends upon the duration of the vergence stimulus (44). Recovery occurs when the original phoria is attained (see Figure 4, right below).

This phenomenon, described as vergence or prism adaptation, may occur if an orthophoric patient wears horizontal prism, such as 10d base out, for an hour. Complete vergence adaptation occurs when cover testing with and without prism does not change, i.e. orthophoria. Upon immediate removal of the prism, cover testing will reveal a moderate esophoria.

These findings demonstrate that elimination of fusional impulses by occlusion, such as cover testing does not result in an immediate loss of vergence related impulses. The slow change in oculomotor position over time secondary to disruption of fusional impulses has been called prism adaptation, vergence aftereffect, or slow vergence (45). These vergence aftereffects are time dependent and receive their input from the fast, fusional, disparity vergence system (46). This is supported by the observation that the amount of diplopia, which is induced by vergence aftereffects, is not affected by either darkness or sleep (47). The position that the eyes are in just prior to going to sleep is the same position that one awakes with. Thus, the oculomotor position of the eyes is not altered by darkness or sleep.

The total disparity induced vergence response is made up of the sum of the fast fusional and slow adaptive
response (48). A sudden disparity vergence stimuli, induced by a change in fixation or by prism, results in an initial fast fusional vergence response. Ogle & Prager (43) pointed out the purpose of the slow adaptive response is to eliminate the stress of the large demand on the fast fusional vergence system. The reduction in the demand on the fast system occurs as a result of a negative feedback loop in the fusional system. An increase in the slow adaptive system results in a decrease in demand on the fast vergence system making it easier for the fast system to respond to subsequent disparities (49).

Slow vergence or vergence aftereffects, extensively described by Schor (48) and Sethi (49), are not only important to the normal person in reducing the ocularmotor error but are extremely important in the DEX(T) and somewhat less important in the basic X(T). This mechanism is most likely responsible for the decrease in the apparent XT at near (both temporally and spatially) where both enhanced stereopsis and fusional detail result in sustained binocularity. Slow vergence with its long time constant is most likely responsible for alignment after blinking, thus eliminating diplopia in patients with significant phorias, i.e., DEX(T) (50).

Disruption or elimination of slow fusion or vergence aftereffects may be achieved by sustained occlusion of one eye, since the slow vergence receives its input (negative feedback) information from the fast (disparity driver) or fusional vergence system. Slow vergence or vergence adaptation has been measured and found to be either complete or incomplete. Sustained or repeated occlusion results in a significant increase in the size and temporal characteristics of the deviation in those patients with strong slow vergence systems. Slow vergence reduces the deviation in DEX(T) more at near, since binocular stimuli, i.e., size, complexity and disparity cues, are stronger, resulting in stronger disparity vergence and slow vergence. Sethi & Henson (51) have shown that the slow vergence system responds differently at different viewing distances to maintain a consistent ocularmotor phoria. These vergence aftereffects tend to be larger at near and in downgaze. Slow vergence movements, also, result in orthophorization with an antimetric prescription across the whole ocularmotor field, i.e., with induced spectacle prism there is no alteration in the measured phoria in different position of gaze (51,52).

Sethi & Henson (51) postulated that there is a cortical memory map for each position in the motor field which is associated with a specific amount of innervation to maintain binocular vision. In patients where the slow adaptive vergence system is weak or incomplete, occlusion will have a minimum effect on the angle of deviation. Thus, one would predict that the more often the exotropic patient deviates, the greater the propensity of the deviation to appear as a basic XT and the weaker the slow vergence system. Inclusion of slow vergence into a block design control system analysis as described by Hung (53) and Cooper (50) is presented in Figure 5, next page.

Scobee (54) in 1952 reported that 24 hours of occlusion increases the near deviation in a substantial number of X(T)s. Burian (10) used this principle of occlusion to classify DEX(T) patients into two groups, simulated and true. He defined a simulated DEX(T) as a DEX(T) whose near deviation increased after 30 minutes of occlusion so that the distance and near deviations approximated each other. In other words, the deviation changed from a DEX(T) to a basic X(T) and the calculated distance near AC/A decreased. But in reality, monocular occlusion eliminated vergence aftereffects which artificially altered the AC/A.

Burian & Franceschetti (24) reported that the change in deviation with occlusion occurred in approximately 60% of the DEX(T) population. The other 40% who are unaffected by occlusion are known as true DEX(T), i.e., distance/near relationship is unaffected by occlusion. Thus, distance/near AC/As are high before and after occlusion in the true DEX(T).

Since both objective and gradient AC/As in the true DEX(T) have been shown to be normal, Cooper et al (40) postulated that proximal convergence is responsible for the discrepancy between post occlusion distance/near AC/A and gradient AC/A in true DE. The calculated proximal convergence factor for the true DEX(T) is 3.0/D (54), while the normal person has a smaller proximal vergence finding of approximately 1.8/1 ±1.6 (55,56).

Ogle et al also found higher than normal proximal convergence values.
Figure 5 (Cooper & Medow): Combined accommodative and vergence feedback loops for normals and X(T)s. Disparity vergences center receives vergence stimulus (VS) when fixation disparity level reaches a certain level. Tonic vergence is added to the sum of fast fusional vergence and slow vergence adaptor. Accommodative induced vergence changes are increased by the cross links of AC/A. Proximal convergence also contributes to total vergence response. Alteration in vergence response results in immediate changes through the fusional vergence controller with a subsequent change in vergence adaptation. Accommodation has a similar negative feedback control system with an accommodative adaptor reducing the load on the accommodation control center. Similar crosslinks occur through CAC (convergence/acc-conv) crosslinks.
in DEX(T), i.e., 4/1 (38). Basic X(T)s are thought to be affected equally at distance and near by occlusion and usually demonstrate minimal effects. Thus, slow vergence mechanisms are weaker in basic X(T) as opposed to DEX(T).

Niederer & Scott (57) occluded a group of X(T)s, to determine the minimal length of time which would elicit the maximum deviation. Occlusion was for 45 minutes, 1 day, and 5 days. They reported that 60% of the X(T)s increased the angle of deviation after occlusion. This is similar to the percentage reported by Burian & Francescetti (24). They found no difference between 45 minutes and 1 day, occlusion; however, five days occlusion increased the deviation in some and decreased it others. Small vertical deviations (2-3°) not present before occlusion were present in 20% of the patients after occlusion. Five days of occlusion increased the vertical deviation to 4-5°.

The application of prism to neutralize the angle, followed and by remeasurement 30 minutes later, and reneutralization of the angle with additional prism is known as the prism adaptation test (PAT). The PAT elicits results similar to those seen with occlusion (38,59). This is expected since prism neutralization, like occlusion, decreases the disparity vergence signal, thus eliminating slow vergence or vergence aftereffects. Since prism and occlusion produce similar results in DE they may be used interchangeably.

3. +3.00 (Diopter Lenses) Test: Brown (33) suggested that +3.00 D lenses interposed at near could be used to differentiate simulated from true DEX(T). He suggested that +3.00 D would increase the near deviation in simulated DEX(T), indicating the presence of a latent deviation, while there would be no change in the deviation in true DEX(T). However, both von Noorden (16) and Cooper (1), and others, have previously pointed out that a significant change in the near angle with +3.00 D OU is due to relaxation of accommodative convergence secondary to a high AC/A ratio. High AC/A are "more" consistent with true DEX(T) compared to simulated DEX(T), since simulated DEX(T) has normal distance near AC/A ratios after occlusion (40).

If one performs both monocular occlusion tests and +3.00 D lens tests, most X(T)s would be classified as pseudo or simulated DEX(T), since the former test identifies patients with a large slow vergence mechanism and the latter test identifies patients with high AC/A.

Accommodation dynamics in DEX(T) have been studied by Schneider et al (60) using an infrared optometer. They found the latency for accommodation for true DEX(T) was significantly increased by 40-100 msec while overshoot frequency was decreased. On the other hand, simulated DEX(T) had a greater magnitude and frequency of overshoots of accommodation which is thought to be related to a robust slow vergence response, i.e., vergence overdriving the accommodative system.

4. Kushner classification:
Kushner (41), basing his results on our earlier findings (40), categorized 83 basic and DEX(T)s by measuring distance and near deviation with a cover test, gradient AC/A with -2.00 D at distance, and +3.00 D gradient AC/A at 33 cm both before and after one hour of occlusion. Occlusion results at near were used to differentiate simulated from true DEX(T).

Table 1 below is a rearrangement for analysis of Kushner’s data. Distance results are reported in the next to last column. All of Kushner’s patients, who had surgery, received bilateral symmetric lateral rectus recession.

Kushner’s type 1a or true DEX(T), have a high AC/A with both distance near and gradient methods. They account for 11% of X(T)s. Neither proximal convergence nor vergence aftereffects are strong in these patients. Traditional bilateral lateral rectus recessions on patients with true DEX(T) and truly high AC/A ratios, according to Kushner, result in consecutive esotropia at near with good alignment at distance. Kushner advises that if the measured gradient AC/A is high, the patient should be advised of the possibility of consecutive esotropia at near and/or the surgical goals should be modified.

Kushner’s type 1b, true DEX(T), has a high AC/A using the distance-near relationship but a normal gradient AC/A and accounts for 9% of the DE. The discrepancy between distance-near AC/A and gradient AC/A is most likely due to normally high proximal convergence since minimal vergence aftereffects are demonstrated by an increase in deviation at distance after occlusion. If the distance deviation had increased after occlusion then the patients would also have strong vergence aftereffects.

Simulated DEX(T) type 2a and type 2b both have normal gradient AC/A after occlusion. Prior to occlusion, type 2a demonstrates an abnormal AC/A with a +3.00 lens at near but not with a -2.00 at distance. This finding has no physiological explanation other than indicating the variability of stimulus gradient AC/A ratios depicted in Figure 2. Thus, Kushner’s two types of simulated DEX(T) may, in fact, be the same entity which represents large variability in the measurement of a stimulus AC/A. The normal AC/A and the smaller near finding are probably a result of a robust slow vergence mechanism.

Kushner’s data suggest that all simulated DEX(T) and most true DEX(T) have a normal AC/A. The discrepancy between distance-near AC/A and gradient AC/A may be explained by a robust slow vergence system in the simulated DEX(T) and a robust proximal convergence in the true DEX(T).

<table>
<thead>
<tr>
<th>TABLE I: Kushner’s Data* on Exotropia, (Rearranged for Analysis) (see text for details and discussion)</th>
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<td>Basic X(T)</td>
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5. Cover Test Findings:

The cover test should be measured while the patient views an accommodative target at 6 meters and at 40 cm. The average deviation when the patient fixates at 6 m is 29° and at 40 cm it is 9° (31).

The distribution of angular measurements is leptokurvic resulting in few XT's being larger than 50° or smaller than 10°. White (61) has noted that the greatest deviation occurs when viewing at 200 ft. Intermittent values occur while viewing at 60 ft.

Most XT's, who have never been treated, think that they know or "feel" when their eye is deviating or straight. However, casual observation demonstrates that their perception of alignment or deviation is inaccurate.

Ogle & Dyer (38) used fixation disparity methods to provide accurate information about oculomotor coordination while fusion was being maintained. According to their studies, the oculomotor balance obtained during dissociation testing, i.e., cover test, does not indicate true binocular imbalances. They reported that during fusion the oculomotor imbalances found in DEX(T) were often normal and/or the associated phoria was often an esophoria. In no case was the associated phoria close to the magnitude of a dissociated phoria/trope.

Surgery, according to Ogle & Dyer (38), did not alter the fixation disparity curve but did affect the measurement obtained by dissociated means. They concluded that: "The tropia found by clinical dissociation tests are a manifestation of an innervation or oculomotor imbalance not present when fusion is maintained".

6. Concomitance:

Although most XT's demonstrate relative concomitance, Moore et al (62) reported about 24% of their patients had lateral gaze incompatibilities, i.e., limitation in abduction. According to Moore et al, those patients with lateral gaze incompatibility were eight times more likely to have a surgical overcorrection.

Kushner (41), who cites Morton, states that only 5% have lateral incompatibility. Furthermore, Repka & Arnoldi (63) suggest that many lateral incompatibilities are due to errors in measurements from improper prism positioning.

A vertical deviation in the tropic eye has been found in 45-55% of all DEX(T)'s during distance fixation (64,65). This vertical deviation is often similar to Bell's phenomenon in that it does not occur upon initial deviation, but only after the fully manifested deviation has occurred. Jamolsky (66) feels that the superior rectus (SR) muscle is a stronger elevating muscle than the inferior oblique (IO) muscle. Thus, during manifest XT, the adducted SR might cause an elevation or hypotropia of the deviating eye. The incidence of overaction of the inferior oblique muscles (IOOA) in DEX(T), according to Davies (67), is 30%. Similar findings have been reported by Wilson & Parks (68) who noted that 52% of all XT's have IOOA which they first noted around 5 years of age. Davies (67) reported that the vertical deviation was more often found in distance testing and absent in near testing. Of the patients having a vertical deviation as identified by Davies, 62.9% had a primary vertical deviation without IOOA, 32.5% had a primary vertical deviation with IOOA, while 4.6% had non-dissociated vertical deviation.

7. Temporal Characteristics:

Most exotropic deviations are intermittent and alternating (of fixation). Alternation takes approximately 80 msec (69). This is approximately the same time for a large saccade.

Schlossman & Boruchoff (32) reported that 85% of all XT's are intermittent, 9% are constant alternators, and 6% are amblyopic. They were the first to use the term intermittent exotropia to include the majority of DEX(T)s and basic XT's.

The first author (1) has suggested that many of the previously classified constant, alternating or minimally amblyopic XT's were most likely intermittent if examined carefully. One must note the position of the eyes before disassociating with a cover test, since an XT may be inadvertently broken down by occluding the eye during visual acuity measurements. They will be incorrectly classified as a constant XT.

Amblyopia associated with XT is usually secondary to anisometropia (not strabismus) and minimal in amount (65).

The deviation is usually more latent at near than at distance. Burian & Smith (70) reported that the angle of deviation increases by 25% when changing fixation from 20 to 100 feet. Also, approximately 10% dramatically change their temporal characteristics, e.g., become constant. The difference in frequency noted between distance and near fixation has been ascribed to: high A/C, proximal convergence, slow vergence (vergence aftereffects), larger retinal disparity, enhanced binocular visual acuity and/or greater angle subtended by fusalional stimuli (1). As previously mentioned, the A/C probably has minimal effect on either the magnitude or frequency of the deviation.

The deviation can be triggered by a myriad of situations and stimuli, such as inattention, daydreaming, distance viewing, fatigue, illness or bright sunlight. Deviating in sunlight, resulting in closure of an eye is so common in XT, that any child with a history of monocular closure of an eye must be assumed to have an XT until otherwise proven.

This photophobia from a photic stimulus leading to eye closure has been assumed to be due to a dazzling of the retina so that fusion is somehow lost (17). Wirthshafter & van Noorden (71) have shown that light adversely affects fusional convergence in XT. Additionally, monocular closure has been induced by artificially increasing illumination. Eustace & Wesson (17) postulated that sunlight causes an XT since, statistically, the closer to the equator one lives the greater the incidence of XT. Romano (18) has suggested that elimination of sunlight by hats with brims might eliminate or reduce the deviation. Wang & Chrysasanthos (72) investigated the relationship between anomalous retinal correspondence (ARC)/normal retinal correspondence (NRC) and monocular eye closure. Monocular closure in XT occurred in 90% of the patients with NRC and only 35% of the patients with ARC. They concluded that this is evidence that eye closure is performed to avoid diplopia and confusion. However, this is conjecture since DEX(T) patients with NRC do not complain of diplopia or confusion. (Also, high correlations do not prove cause and effect.)

Recently Wiggins & von Noorden (73) evaluated the report of diplopia as the reason for monocular eye closure in DEX(T). They also video-recorded eye closure responses to bright light in an attempt to determine if the deviation occurred prior to closure of the eye. They reported that closure occurs before deviation and that no subject perceived diplopia. Contrary to the report of Wang & Chrysasanthos (72), they found no relationship between retinal correspondence and eye closure. Wiggins & von Noorden also did not find any effect on fusional convergence with increased illumination. Wiggins & von Noorden (73) concluded: "No satisfactory explanation can be offered at this time to explain the high prevalence of monocular eye closure in intermittent exotropia."
Inability to maintain alignment. Thus, eye closure before exodeviation might occur to eliminate the need for ARC or the possibility of diplopia/ confusion or discomfort avoidance from the stimulus.

In any case, strong non-visual stimuli, such as talking, trigger exodeviation while strong visual stimuli, i.e., large stereo targets, eliminate exodeviation. Therefore, during cover testing, when attention is high, neither a manifest nor a latent exodeviation may be observed when one in fact exists. Exodeviation is easier to elicit with a muscle light than with an accommodative target. Binocular realignment is often obtained with a blink of the eyes which can occur secondary to appropriate stimulus presentation, i.e., stereo target or upon verbal command. The vergence response is quick and accurate.

Parents, unfortunately, often take this as a sign that the child is lazy or inattentive. Unlike esodeviations, a parental report of XT is probably more valid than the examiner's findings.

3. Fusional amplitudes:

Ergographic measurements of both sustained and repeated measurements of convergence in X(T), according to Berens et al (74), do not show a decrease in the amplitude of convergence nor does sustained and repeated convergence produce symptoms over time. Convergence ranges in X(T), surprisingly, are normal when compared to an orthophoric patient.

If Sheard's criterion is applied (where the demand should be equal to twice the reserve), then the average fusional amplitude of an X(T) should be at least 58° (2X the mean deviation of 29°). X(T) patients lacking these large fusional ranges can easily and readily be trained to have 80° fusional convergence. However, these enlarged fusional ranges only have minimal effects on the exodeviation.

Fusional ranges are larger with stereo targets. At near, stereo targets initiate realignment (from exodeviation). However, during reading or CRT (VDT) viewing, both stereopsis and sharp accommodative cues are eliminated, thus making it difficult for either the accommodative or the vergence system to respond appropriately. The result is often anasthesia.

Base-in prism or divergence fusional amplitudes are usually less than the angle of deviation (1,38). This difference might be due to the control system initiating a divergence movement. Accommodation -vergence and fusional divergence may result in NRC (75). An exotropic deviation, however, is almost always initiated by a supranuclear eye movement which is related to the version control system with resultant harmonious ARC. (See Morgan's theory under sensory-motor findings, ARC p 198.) The difference in correspondence during different types of vergence movements provides further evidence that the X(T) may not be a result of either relaxation of convergence or loss of fusional divergence. Furthermore, if X(T)s were the result of a relaxation or failure of convergence, then one would expect the angle of deviation to be less than the fusional divergence amplitude. However, this is not the case.

Breinin & Moldaver (76) have performed electromyographic studies which clearly demonstrated that the lateral rectus muscle has a maximum firing potential which occurs during exodeviation while the medial rectus muscle decreases its firing rate (at the same time). This finding is consistent with divergence being an active process, and not a relaxation of convergence.

B. Sensory Findings

1. Stereopsis & physiological diplopia:

Flax (77,78) has made the observation that X(T)s will maintain binocularity when there is an advantage to being binocular (at near with stereopsis) and will often deviate when there is no real advantage to binocular alignment, as in distance viewing. The deviation often increases when fixation changes from 20 to 200 feet where stereoscopic vision becomes poor (70).

The first author, Cooper, (1) stated that during alignment X(T)s have normal binocular findings, i.e., they have normal stereocuity, binovel fixaton, and NRC.

Gross & von Noorden (79) recently reported that 60% of X(T) patients have poorer than 60 seconds of arc stereocuity (i.e., less than normal limits). This is at odds with other reports and our previously noted observations.

Rosenbaum & Sinathacopoulos (80) measured both near stereocuity in X(T)s with the Titmus and Randot Stereocuity Tests; and distance stereocuity with the "BVAT" (Mentor's CRT monitor acuity measuring system). They found an average near stereocuity on the Titmus Test of 41.1 sec arc and 31.1 sec arc on the Randot Test. Distance stereocuity findings were reduced compared to normals however.

This reduction in distance stereocuity was likely due to the significant number of X(T)s deviating at distance when measurements were taken. For purposes of calculation, they also recorded a failure to perceive stereosc as "400 sec arc." This would tend to raise the mean numerical value artificially. (The median value would have been a more valid statistical measure since this measure is not biased by the extremes.)

Common to many such studies, it should also be noted that since the smallest disparity target on the Titmus Test is 40 seconds of arc, and on the Randot Test, 20 seconds of arc, neither test provides a true measure of stereocuity. The normal near mean stereocuity for the general population is 20 sec arc SD ±10 sec arc. Therefore, these tests cannot accurately measure stereocuity, since 50% of the population have a stereocuity better than 40 sec arc, which is the limit of the Titmus Test.

Appreciation of random dot stereograms demonstrates that during times of normal binocular alignment there is bifoveal fixaton (81).

Suppression, if present during normal binocular alignment, occurs only during dichoptic viewing (each eye sees a different image, e.g., physiological diplopia, bird and cage targets) of first degree targets. This suppression may be noted during cheiroscopic tracing and measurements of physiologic diplopia. Pritchard & Flynn (82) have reported that 74% of X(T)s suppress physiological diplopia and 6% have inter mittent suppression. Since normal binocularity is found with stereoscopic targets, and suppression is observed with first degree targets, sensory responding in this condition is stimulus mediated.

During exodeviation sensorial functioning changes dramatically. Fine stereops is lost (1). The patient may exhibit: NRC (83-85); an altered (adapted) projection value such as in harmonious or unharmonious ARC (86-91); or a lack of retinal correspondence (91,92). These binocular findings may be altered by the presence of regional or total suppressions. These suppressions may be shallow or deep.

2. Suppression & panoramic viewing

X(T) patients, according to Cass (27) and Costenbader (12), have extension of the peripheral field of view which is known as panoramic viewing. Cooper & Feldman (86) used a translucent hemisphere to present peripheral visual stimuli, and an EOG to monitor eye position during normal alignment and exodeviation. They demonstrated that during deviation the exotrop has an extension of the binocular
which occurs only during exodeviation. Jampolsky (84) used a Riker prism and a red lens to measure suppression in X(T)s. He reported that suppression extends from the fovea of the deviating eye into the temporal retina to the diplopia point (the point where the object of regard falls on the deviating eye). Jampolsky also reported that the nature of the stimuli influenced suppression patterns.

Similar findings were initially reported by Travers (95) who found two suppression zones, one at the fovea of the deviating eye and another at the diplopia point.

Pratt-Johnson & Wee (96) used red-green anaglyphs with a Lee Screen and polaroid lenses to measure suppression areas. Using polaroid lenses to dissociate the eyes, they found that X(T)s had a strong suppression zone extending from the deviating fovea to the diplopia point (See Figure 7, below). Contrary to Jampolsky (93), they found harmonious ARC (HARC) without evidence of suppression with red-green targets peripheral to the fovea of the deviating eye. They also reported, like Travers (95) two suppression areas, one at the fovea of the deviating eye and the other at the diplopia point. Like Jampolsky, they reported that

field of view in which the enlargement and spatial shift of the visual field exactly match the angular measurement of the deviation (See Figure 6, above). Thus, they experientially proved Cass (27) and Costenbader’s (12) observations of panoramic viewing.

One can easily demonstrate panoramic viewing in X(T). First, measure and plot a binocular confrontation field with eyes aligned. Then repeat the procedure with an eye exodeviated. The binocular field will most likely be larger by the amount of the deviation.

Costenbader (12) has stated that X(T) has NRC with or without suppression. He reported that visual confusion was present in 61% of DEX(T) which he felt supported his contention concerning NRC. Bair (31) noted visual confusion present in 316 out of 528 DEX(T)s. Neither author defined how they measured visual confusion.

Most authorities disagree with Costenbader and Bair, who reported that patients with DEX(T) generally do not report diplopia or confusion (1,9,11,12).

The major proponents of suppression theories are Jampolsky (23,92) and Knapp (94) who maintain that X(T)s have binocular, hemiretinal, temporal suppression

![Figure 6 (Cooper & Medow): Experimental design in Cooper J, Feldman J: Panoramic viewing, visual acuity of the deviating eye, and anomalous retinal correspondence in intermittent exotropia of the divergence excess type. (Am J Optom Phys Opt 1979; 56:422-429). OD is fixing a light source behind a translucent screen (©). When the left eye is deviated (---) both visual acuity at the objective angle and binocular field of view are measured. The measurements were repeated with the left eye aligned (...). Eye movements were monitored. Results show during deviation simultaneous perception of fixation target (©), 20/20 visual acuity in the deviating eye, with accurate spatial projection of the peripheral target. The HARC (harmonious anomalous retinal correspondence) was associated with the increase in the field of view while deviating i.e. panoramic viewing.](image1)

![Figure 7 (Cooper & Medow): Various reported suppression patterns for X(T). OD is fixing; OS deviating. (All suppression patterns described are with the OS deviating.)

Pattern 1: two suppression areas corresponding to the fovea and point zero (diplopia point) of the left eye. Pattern 2: dumb bell shaped suppression zone extending from diplopia point to deviating fovea. Pattern 3: "D" shaped suppression zone including deviating fovea and diplopia point. Pattern 4: temporal hemiretinal suppression. Note targets on the left side (animals) are seen by the left eye and seen where they are in real space demonstrating HARC.](image2)
suppression patterns varied with the stimuli.

Awaya et al (85), using a phase difference haploscope, found that most patients with DEX(T) during exodeviation had two dense suppression scotomas, one corresponding to the fovea of the deviating eye and the other at the diplopia point. This dense suppression could be broken with a rapid oscillation technique revealing NRC diplopia.

Recently Melek et al (97) evaluated suppression and retinal correspondence in 21 X(T)s using a Goldman (bowl) Perimeter while the subjects viewed the fixation target with Bagolini Striated Glasses. Fixation and ocular position was monitored with frequent occlusion of the fixing eye. They reported that 52% of the manifest X(T)s had temporal suppression (10% demonstrated temporal suppression in the deviated eye, 10% temporal and nasal suppression in the deviated eye, and 24% temporal suppression in both eyes). The other 48% had suppression scotomas (38% had suppression of the diplopia point and a sector of the peripheral temporal retina, while the other 10% not only suppressed the diplopia point and temporal retina, but also the fovea). On the other hand, during normal alignment none of the X(T)s demonstrated suppression scotomas. Interestingly, none of their subjects demonstrated ARC with the Bagolini Striated Glasses during exodeviation.

These findings are in agreement with studies reported by Pruitt-Johnson & Wee (96), Campos (88), Cooper & Feldman (88), and Cooper & Record (87) all whom noted a higher incidence of ARC and suppression with afterimage or anaglyph testing; and NRC with the Bagolini Striated Glasses.

Temporal hemiretinal suppression with NRC in the real world could not work. As seen in Figure 8, right, if the DEX(T) patient suppresses the temporal retina, while the nasal retina has NRC, the patient would not have altered egocentric localization of the objects seen by the deviated eye and severe visual confusion would ensue. Fortunately, DEX(T) patients do not report this phenomenon. If they did they would live in a very confused world.

3. Anomalous retinal correspondence (ARC):

ARC with X(T) was initially reported by Bichowsky (8). He observed a patient who reported NRC on the afterimage test when the eyes were straight and harmonious ARC when the eyes deviated (See Figure 9, next page). This duality of correspondence is unique to X(T). Burian (98) stated that suppression does not always occur during deviation in X(T): "When the deviating eye turns out, there is a simultaneous displacement of the egocentric localization of all visual directions of the eye so that no diplopia occurs. This is anomalous retinal correspondence." Other clinical reports of ARC come from Hugonnier (99), Burian (98), Bagolini & Capabianco (100) and Chryssanthou (101). Campos (88), using Bagolini Striated Glasses with non-disassociating mirrors, found that most X(T)s demonstrate HARC. Campos & Cresi (89) reported that smaller angle X(T)s showed HARC without suppression, while larger angle X(T) often suppressed the diplopia image in the deviating eye. In their previously described Ganzfeld experiments Cooper & Feldman (88) reported that neither fovea suppressed during deviation.
Visual acuity was approximately 20/20 in each eye at the same time and the directional values of each fovea were consistent with the physical space. In other words, the subjective angle was zero. Their subjects had HARC across the nasal retina with an extension to the binocular field, i.e., panoramic viewing. In a subsequent study, Cooper & Dibble (87) using dichoptic anaglyphic stimuli, attempted to identify the depth of the suppression scotomas in the temporal retina previously identified by Jampolsky (84), Pratt-Johnson & Wee (96), and Awaya et al (85). Instead, they found non-suppression of temporal retina with perfect HARC.

The difference in the incidence of AR/CNRC reported is clearly dependent upon the stimulus condition used for testing. Thus, ARC is probably not "wired" in and is modifiable. The stimulus conditions which elicit the greatest number of ARC responses in XT seem to be opposite to that of ET. In XT the more natural the testing conditions, the greater the chance for NRC responses, while the more artificial the environment the greater the chance of an ARC response. Burian (98), Cooper & Feldman (86) and Cooper & Dibble (87) have all reported an increase in ARC responses with afterimages compared to Bagolini Strained Glasses.

These findings are in conflict with Burian's adaptation theory of ARC. Burian suggested that ARC is a sensory adaptation to a motor misalignment. ARC is an attempt to reestablish binocular vision. The more natural the environment of testing the greater propensity for ARC responses on testing. Thus, afterimage testing should provide the lowest incidence of ARC.

But X(T)s do not follow Burian's adaptation theory in that the highest incidence of ARC responses occurs with afterimage testing. Also, immediate post surgical ARC responses are inconsistent with adaptation theories. Further, unlike ET, unharmonious ARC is not common in XT (102).

The best explanation of dual retinal correspondence in X(T) (and possibly ARC in ET) is provided by Morgan's motoric theory of ARC (103), which is based on Urist's findings with afterimages (104): If a vertical afterimage is flashed on one eye while the other eye is occluded, and a version is performed, Urist noted that the afterimages would move with the eye. The lateral movement of the afterimage results in a change in egocentric localization and is called a registered movement. On the other hand, if an accommodative vergence movement is performed instead, the afterimage will not change its egocentric direction. The afterimage (AI) will appear to regress or approach the subject. These movements are known as unregistered movements. (It should be noted in both cases that the eye with the AI was adducted an equal amount).

Urist's findings show that egocentric localization of an AI is based upon the type of eye movement and that projection is not cortically fixed. Accommodative vergence anomalies such as in an accommodative ET would be expected to have non-registered movements. Thus, changes in the deviations due to vergence induced by accommodation-vergence would not result in an alteration of projection of an AI. The result would be NRC. Version related defects as proposed by Keiner (105) would be associated with registered movements and a change in egocentric localization or ARC.

Morgan postulates that during manifest XT, registered movements take place resulting in a change in position and egocentric localization of the AI. Morgan's theory would predict NRC when the XT patient was straight and ARC when deviated. Though Morgan's theory is the most appealing theory of ARC, it fails to account for the discrepancy in findings of retinal correspondence found on various tests, and the rare, but recorded, instantaneous changes in correspondence without an appropriate motor response.

Sperling (106) has shown that retinal disparity and motor information can easily be mathematically combined to give an accurate prediction of relative depth no matter where the eyes are postured.

Boucher (107), using common visual direction, mapped out the horopter of a deviating X(T). Ocular position was monitored with an infrared eye monitor system. The shape of the horopter measured during exodeviation was similar to the horopter obtained during normal alignment except for a larger Panum's area. This finding suggests dual retinal correspondence with ARC occurring across the entire visual field. Boucher states that the X(T) patient overcompensated for distance localization since the horopter was closer to him than to a normal person.
4. Lack of correspondence:

Some X(T)s have a third type of sensory adaptation mechanism in which there is an absence of retinal correspondence during exodeviation. Each eye acts independently without any spatial communication, as if there were two separate worlds. For example, the manifest X(T), when viewing dissimilar right and left targets through a stereoscope, will see both the right and left pictures at the same time without being able to spatially relate them. Depending on stimulus conditions, the X(T) changes from NRC to ARC to a lack of correspondence. Triggering mechanisms are stimulus dependent.

The above findings are important in understanding why the X(T) patient deviates whenever stereoscopic information or visual attention is lacking. At near, where stereopsis is more important and associated with attention, proprioception, and touch, exodeviation is expected to occur less frequently. Most deviating X(T)s will align their eyes when presented stereoscopic stimuli such as the Titmus Stereoscopic Test, Random Dot Stereogram, or Straw and Pointer Test (stereocuity is normal).

The habitual use of disparity-driven vergence to maintain fusion causes the feedback loop to slow vergence to reduce the deviation, keeping the deviation latent in the simulated DEX(T), while proximal convergence reduces the deviation in the true DEX(T). If there is a loss of visual attention, or if fixation changes to distance where there are fewer stereoscopic cues to elicit binocular alignment, exodeviation will ensue. During exodeviation motor changes occur which result in changes in egocentric localization, i.e., ARC.

During exodeviation there is an expansion of the binocular field of view known as panoramic viewing. Panoramic viewing extends the peripheral field of view and the motion detection system of the eyes. With appropriate visual stimuli, touch or attention, orthotropic realignment ensues with resultant NRC.

III. THEORIES OF ETIOLOGY

A. Anatomical/Mechanical

An anatomical theory of etiology was first proposed by Bielechowsky (8). He maintained that the deviation was due to anomalous positions of the orbits. Parks (108) has suggested that the divergent position is congenital. In support of the anatomical theory, Knapp (109) noted that XT is often associated with craniofacial anomalies such as hyperelorism and oxycephaly where the (inter)pupillary distance (PD) is very large. However, wide PDs should result in a relative convergence insufficiency type XT. Additionally, there is no data to suggest that X(T) patients have more divergent orbital axes (than normals do).

Mechanical theories based upon improper insertions or adhesions of the extraocular muscles have been advocated. However, there have been no systematic studies supporting this theory. Additionally, transposition studies performed on monkeys do not support either a mechanical or anatomical theory of etiology (110,111). In monkeys an XT cannot be created unless the medial rectus muscle is disinserted without spontaneous reinsertion (112).

Numerous transposition studies have demonstrated that superior and lateral recti muscles can be transposed with normal concomitant horizontal movement restored in a few days (110,111). These studies place both mechanical and anatomical theories on tenuous ground.

B. Active Divergence

Duane's original concept of active divergence has electrophysiological support. Blodi & Van Alten (113) have demonstrated that when an XT starts to manifest itself, the lateral rectus muscle of the deviating eye begins to fire. According to Brennich & Moklaver (114), the lateral rectus continues to fire while the eye is divergent, having its maximum potential during divergence. Active divergence is also supported by the fact that the angle of deviation is outside the fusional divergence range (38). This finding is explainable if divergence were due to a relaxation of convergence.

Tambler, Jampolsky & Marg (115) believe that X(T) is a result of relaxation of convergence. They state that "Our binocular electromyograms of the intermittent exotropia are similar in every detail to the known diminution of convergence in the normal individual." The fact that an X(T) patient assumes a position similar to Bell's phenomenon found when the eyes close during sleep or death further support a theory of relaxation.

C. AC/A Ratio

Jampolsky (34) and Parks (35,108) have suggested that DEX(T) is a result of a high AC/A ratio. By clinical definition, the use of distance-near findings to calculate an AC/A guarantees a minimum AC/A of 10/1. However, as previously discussed in the section on AC/A, gradient AC/A's in DEX(T) are within normal to high normal limits. Objective AC/A findings are essentially normal. If AC/A ratios are high, then lateral rectus muscle recessions should result in postsurgical ET at near. Also, high AC/A accommodative induced convergence, as reported by Seaber (116), should result in sustained blur whenever DEX(T) patients move their eyes from a deviated position to alignment. This is a rare occurrence. Lastly, AC/A models do not explain the initial distance deviation.

D. Phylogenetic

Posner (117) observed that phylogeny and ontogeny demonstrate a migration of the visual axes from the lateral to the frontal position while oculomotor control has moved from the midbrain to the cortex. According to Posner, manifest XT represents a loss of cortical decerebralization which is an atavistic trait. Though this theory is conjecture, it is consistent with the binocular functioning of the chameleon, which is a naturally occurring X(T). (See further below.)

E. Hemiretinal Suppression

Jampolsky (22,23,34) and Knapp (83,94) assumed a simplistic approach to differentiating X(T) from exophoria using suppression. Jampolsky (22) states: "Intermittent exotropia evolves from an exophoria as a result of the development of hemiretinal suppression during visual infancy". This statement assumes that X(T) has NRC when deviated. Though there is evidence of suppression with NRC, the bulk of studies suggest ARC. There is no scientific evidence to support hemiretinal suppression during fusion. If hemiretinal suppression occurs with ARC, the X(T) patient would be living in a world of confusion. Objects temporal to the fovea of the deviating eye would be projected almost straight ahead.

F. Genetic Anomaly

Many authors feel that X(T) is a genetic anomaly. In Costenbader's study of 412 patients with X(T) 204 were present at birth, 88 appeared before one year of age, 196 appeared between age one and five years, and only 24 appeared after five years of age (12). Similar findings have been reported by Krzystkowa & Pajakowa (28). However, Hall (118) found only 37% of X(T) occurs before the age of 2 years. More recent studies suggest that X(T)
may be considered a normal finding up to the age of 6 mos (119). After that age any X(T) is considered indicative of a future strabismus and should be watched carefully. X(T) has a predilection for blacks and women. Unlike ET, X(T) is rarely found after systemic illness.

Besides the early appearance, strong support for X(T) being a result of a genetic anomaly comes from hereditary patterns reported by Jampolsky (22), Parks (108), Posner (117), and Binion (120): Knapp (121) reported a family history in 28% of the X(T) cases and Burian & Spivey (122) in 21.5% of the cases. Knapp (83) further states that the percentage of family related X(T) would be higher if X(T) was more accurately studied: many X(T) cases go unnoticed or unreported due to the infrequency of the XT.

G. The Chameleon Theory

Previous theories have not explained all or even many of the sensory and motor findings of DEX(T). The first author has presented and published a theory which attempts to include most of the sensory-motor findings in X(T): 

Chavasse (123) noted that during the course of evolution from vertebrates to primates, the eyes moved from a lateral position to a frontal position. He suggested that the physical position of the eyes was related to either protection or aggression. Protective mechanisms were dependent on the largest possible total field of vision while the aggressive reflexes were initiated by binocular fixation of the prey. Chavasse went on to say: "The disadvantages of having the total field of vision limited to achieve maximum binocularity must have been outweighed by other factors affording enhanced protection, such as the acquisition of neck movement, especially in the upright posture, the reduction of the chance of attack from behind by the assumption of arched life, the use of the hands both for protection and aggression..." (p.25)

Walls (124) and Prince (125) also noted that the position of the eyes, i.e., frontal or lateral, was not based on phylogeny but on predation. Those animals that hunt have frontal placement of the eyes with overlapping binocular visual fields to improve stereopsis, while hunted animals have lateral placement of the eyes to increase peripheral vision and motion detection. This larger teleologic sensing device is important in detecting danger: for example, the rabbit has almost a full 360° field of vision while man has 180° field of vision. Prince (125) stated that animals involved with manual manipulation need to have frontal placement of the eyes for improved stereopsis.

Non-predaceous mammals high on the evolutionary scale survive on the basis of manipulation. Both manipulation and predation require precise spatial localization as is obtained with stereoscopic vision. The evolution of man, which favors manipulation to make tools, has eliminated the need for panoramic viewing preferring overlapping fields of view which give rise to stereopsis.

DEX(T) seems to be a functional compromise between the two visual systems. They have both stereoscopic vision when it is advantageous and panoramic viewing during exodeviation when there are few stereoscopic cues present (1). Both stereopsis and panoramic viewing are thus attainable in the same species.

During near vision, where retinal disparity cues are plentiful and the stimuli have a lot of detail, the eyes are aligned. An experienced clinician will attest to the fact that DEX(T) patients rarely deviate during stereopsis testing, i.e., Titmus Stereo Test. Their visual systems can identify disparity targets which elicit bilateral fixation (1). Bilateral fixation eliminates disparity vergence and stimulates the slow vergence system (vergence aftereffect) through a feedback loop proposed by Schor (45,46,48). Sustained utilization of slow vergence in simulated DEX(T) reduces the load on the disparity vergence system and thus reduces the apparent phorias.

True DEX(T) has a weaker slow vergence system and substitutes abnormally strong proximal convergence which eliminates the need for sustained fusional vergence. Only a small percentage of true DEX(T) cases, who have normal proximal vergence and vergence adaptation, use their high AC/A to reduce the near deviation. Basic X(T)s have normal stereopsis at near and also align normally with appropriate stimuli. However, since slow vergence is less effective in this population, they are more apt not to align binocularly under ideal stimulus conditions, i.e., stereacuity.

Orthoptic treatment emphasizing convergence amplitudes increases vergence adaptation and results in many basic X(T)s becoming DEX(T)s, i.e., the near deviation decreases in size and amount of time exodeviated.

The system is spatially dependent (1) relying on both proximal (near) and stereoscopic cues. If motor fusion is measured in DEX(T) using flat fusion targets, intermittent suppression with poor fusion ranges is usually noted. If simultaneous perception targets are presented, exodeviation often occurs with resultant suppression and/or ARC. On the other hand, if digital manipulation, proprioception, and/or attention are utilized by the DEX(T) patient, binocular alignment ensues. These findings are the opposite of ET which responds more vigorously to first degree targets.

Upon distance viewing or during relatively passive viewing there is no need for stereoscopic information, thus an eye exodeviates. During exodeviation there is an increase in the binocular field of view equal to the angle of deviation and fine stereopsis is lost. The system during exodeviation has a rudimentary binocular system evidenced by measurement of a horopter (93). Specific sensorial binocular function in X(T) during deviation is controversial.

It seems that DEX(T) has a dual retinal correspondence system: ARC when deviated, and NRC when straight. Retinal correspondence varies with motor position so that the angle of anomaly covaries with the exodeviation. ARC also changes with stimulus conditions. Morgan (103) has shown that this alteration between ARC and NRC might be explained on the basis of motor induced sensory changes resulting in covariance.

IV. TREATMENT OF X(T)

Treatment for X(T) may be divided into surgical and orthoptic (i.e., non-surgical). Which form of therapy is advised is biased by different academic training based on different bodies of information or differing interpretations of same and the different treatment capabilities and options imposed by education, training and licensing authorities.

Orthoptists, in the United States, using a medical model, are biased towards pharmaceutical and surgical intervention. Orthoptists advocate both orthoptics and/or surgery. Orthoptists tend to employ mostly home-based orthoptics. Optometrists tend to use in office orthoptic therapy supplemented with home orthoptic therapy.

None of the therapeutic regimens used have undergone the scrutiny of a prospective double masked clinical trial. Additionally, specific techniques used in
both surgery and orthoptics vary tremendously from author to author.

Criteria for success in treatment are not uniform: One author considers a "cure" to be any residual strabismus less than 15º, while another considers a "cure" to be a 100% elimination of the deviation, with elimination of suppression, and normalization of fusional ranges and stereocuity.

With the above in mind we will attempt to review current treatment strategies.

A. Orthoptics

1. Active orthoptics:

Traditional orthoptic therapy has been based on the concept that DEX(T) is a result of inadequate motor fusion. Historically, treatment has been directed towards improving deficient convergence amplitude ranges.

In 1914, Reber (126), one of the first to report orthoptic results, stated that 75% of his patients with DEX(T) were cured with such exercises. Bulson (127) in 1926 stressed the use of orthoptics with prolonged conscientious increasing effort. Duane (2) in 1897 had stated that surgery should be avoided until all other methods have failed.

Dunnington (11) in 1927 denied any benefit from orthoptics but Berins, Hardy & Stark (128) reported in 1929, 19 cases of DEX(T) treated orthoptically; 16 were cured or significantly improved, and only 3 showed no change.

The bulk of early therapy utilized the synoptophore and flat fusion targets to build fusional disparity vergences. Within a short period of time most DEX(T) patients showed enormous fusional convergence ranges.

Unfortunately, this ability does not always result in a permanent change in the exodeviation. Often, there is a short term reduction in the frequency or in the angle of exodeviation probably due to vergence aftereffects.

Moreover, many surgeons, fearing overcorrections, when determining the amount of surgery to perform in this condition, want to eliminate the effect of vergence exercise aftereffects, and advice the cessation of such convergence therapy for 6 weeks prior and/or patching before measuring the total deviation for surgery. One study, however, by Shipman & Veronneau-Trotman (129) demonstrated that preoperative convergence therapy had no effect on surgical outcome.

It is not surprising that convergence training by itself has a minimal effect on the deviation. As originally noted by Sugar in 1947 (9) DEX(T) cases have normal convergence fusion amplitudes. Therefore, the deviation is probably not due to a failure of fusional convergence. In hindsight, therefore, one would expect improvement of fusional convergence amplitudes to have only a minimal effect.

In the 1950s, diplopia awareness was added to convergence training to make the patient aware of the deviation (130). Pathological diplopia was taught by placing a red lens over the non-deviating eye while the patient viewed a "muscle light" in a darkened room. The light was first presented at near and eventually moved to distance, which resulted in the stimulus subduing a smaller angle and the retinal image of the light moving closer to the fovea. The subject was required to maintain diplopia while the room illumination was slowly increased. Then the red filter was replaced by the progressively less dense red filters of the Bagolini filter bar. The last step was to decrease the brightness of the muscle light, while maintaining diplopia awareness.

A similar red lens diplopia technique was used by Sanfilippo & Ciapane (130), (131), combined with traditional techniques to improve fusional convergence. They treated 31 exotropes for 5 to 22 sessions (average 7.5 visits). Initially 81% were considered poor functionally. They reported that 84% of DEX(T) cases studied showed a significant improvement: 64.5% were cured, and 9.7% were classified as "good" and 9% "fair".

The five year study (131) conducted by Sanfilippo & Ciapane demonstrated a maintenance rate of 52% cured and 32% "improved". Females did significantly better than males. Most of the improved cases had a pre-orthoptic treatment deviation of 20-25º.

Similar findings were reported by Mann (132) who found 60% of her cases were cured and another 15% showed definite improvement. Durran (133) reported 20 of 40 X(T)s treated with orthoptics were cured.

Some patients showed improvement even after orthoptics was terminated. Duncan (134) reported that 10 of 20 (65%) X(T)s treated solely with orthoptics were cured. The average followup time was 19 months after cessation of orthoptics.

Cooper & Leyman (135) in 1976 reported a retrospective study with a minimum 1 year followup. They reported the following: with occlusion treatment, 36% were classified as "good"; with surgery, 42% were classified as "good"; with surgery and orthoptics, 52% were classified as "good" (the majority of the third group had deviations greater than 25º); and with orthoptics, 59% were classified as "good". An optometrist, Duckman (136), re-evaluated Cooper and Leyman's orthoptic results and noted that those with an exotropia greater than 25º were rated "good" 35% overall, while those with deviations less than 25º were rated "good" 60% overall.

Alzheimer (137), an orthoptist, in 1972 reported a comparison of 29 X(T)s (16 intermitent) treated with surgery alone to 23 X(Ts) (13 intermittent) treated with orthoptics alone. Treatment consisted of total occlusion to eliminate suppression, followed by application of Fresnel prisms to eliminate the exodeviation; and convergence exercises. It was noted that "surgical and non-surgical treatment produced fairly equal functional results."

Another orthoptist, Chyssanthous (138) reported in 1974 her retrospective orthoptic treatment study on 27 X(T)s. Therapy consisted of home based training including occlusion, diplopia awareness, and stereograms to increase fusional ranges. She reported that before training 85% were "poor", 11% were "fair", and 4% were "good". After therapy 67% were "excellent" (phoria only with good vergences), 11% were "good" (phoria only with acceptable vergences), and 11% were "fair" (X(T)). Long term followup (6-20 months) revealed 37% were still "excellent", 30% were "good", and 23% were "fair", while only 11% remained "poor".

Daum (139) reported his results in 1984 in 18 DEXT cases (age 4-56 years) 13 of whom had an intermitent deviation. Optometric orthoptic therapy was mostly home based and was carried out for an average of 5.5 weeks (range 1-16 weeks). Elimination of the exodeviation occurred in 33% with partial success in 36%. Daum noted improved success in patients with a small deviation, low AC/A, and no vertical deviation. Daum's treatment regimen was very brief with reliance on home therapy.

One of the current optometric treatment strategies was based on the findings of Brock (140)(1966) and developed by Flax (77,78) (1968,1963). Treatment was based upon the finding that DEX(T) cases are binocular when there is an advantage, i.e., in the presence of stereopsis, and exodeviate when disparity cues are lacking. Therapy employs operant conditioning techniques in which the stimuli used in the
beginning of therapy are those in which the patient can easily attain normal binocular alignment, i.e., large, detailed stereo targets presented at near.

Therapy continues along a spectrum from third degree to first degree targets until normal alignment can be attained even in the absence of disparity cues, i.e., superimposition targets presented at 20 feet or more. The hardest orthoptic task for the X(T) patient to perform is chiascopic tracing. For some unexplained reason, X(T)s demonstrate less suppression when tracing in a mirror chiascope as compared to a Brewster chiascope.

Increasing fusional ranges is of minimal importance according to the Flax/Brock model since there is a minimal deficiency in this area. Flax (69,70) feels the development of diplopia awareness is also unimportant since postural awareness keeps the eyes in proper alignment.

Due to the apparently high A/C/A, eso fixation disparity, and accommodative facility deficit, Flax feels that plus lenses should be prescribed for near vision use. However, as previously stated, the apparent high A/C/A ratio and eso fixation disparity measured are probably secondary to proximal convergence and/or fusional aftereffects. Dynamic accommodative studies demonstrate subtle accommodative deficits which are not, however, clinically relevant.

Flax’s model of therapy without the utilization of a near prescription of plus lenses is consistent with the first author’s chameleon model. However, the first author advocates the utilization of red lens diplopia awareness therapy prior to employing the Brock/Flax therapeutic regimen. The purpose of diplopia awareness is to provide the patient with an additional sensory biofeedback mechanism to acknowledge the exodeviation. Once the patient achieves diplopia awareness, therapy consists of conditioning the disparity vergence system to eliminate diplopia via the fusional vergence system. The first author advocates the use of various reinforcement contingencies to assure appropriate binocular responses.

The second phase of the first author’s therapy is identical to the Flax/Brock model in which fading procedures are used to slowly eliminate retinal and contour cues. The patient at the end of therapy demonstrates NRC, elimination of suppression, and normal binocular alignment in the absence of disparity or fusion cues.

Constant normal binocular alignment is then maintained by disparity vergence and “postural awareness”. Disparity vergence, through a feedback signal to the slow vergence system reduces the phoria, thus eliminating the exodeviation. Although the basic exodeviation is still present and can be elicited through prolonged occlusion, the binocular system has functionally decreased the fusional demand by using slow vergence or fusional aftereffects.

Goldrich (141) reported in 1981 a retrospective study of 28 DEXT cases (age 5-35 years) treated with the Brock/Flax techniques. All patients had deviations less than 35°. Weekly in-office training was supplemented with home therapy. Therapy consisted of motility, accommodative facility, near and distance vergence, anti-suppression and jump duction techniques. Therapy consisted of 45 minute in-office therapy with supplemental home therapy. Success criteria were very rigid. He reported 72% classified as "excellent" (average number sessions = 29), 10% were "good", 14% were "fair", and only 3% remained "poor". In other words, 96% improved while 82% were transformed from "strabismus" to "no strabismus with comfort" in approximately 7 months.

Ludlum (142) in 1961 reported a retrospective study of vision training in 38 X(T)s who had at least 8 sessions of therapy. Therapy was mostly in-office 45 minute sessions 2-3 times a week (mean 23 sessions, range 10-76). Therapy was well detailed and included motility, accommodation, fusion amplitude, anti-suppression, and accommodation-convergence training. Ludlum also included occlusion techniques. Criteria for complete success was allowing the deviation to occur less than 1% of the time with immediate recovery of fusion based upon diplopia. Partial success was defined as a deviation occurring between 1-5% of the time with recovery of fusion occurring immediately upon deviation. Complete success occurred in 52%; partial success (strabismus up to 5%, a need for prisms, and/or a lack of stereopsis) in 40%. Long term results (143) of at least 3 years demonstrated that 63% remained cured.

Eting (144,145) (1978,1973) presented two retrospective studies for a combined total of 23 patients with DEXT. They had at least 24 in-office therapy sessions. According to Eting, 91% of the patients with XT were "cured".

Hoffman et al (146) also reported in 1970 a high success rate (95%). All their patients except one had a deviation less than 30°. The criteria of success and the accurate classification of patients provided by Eting was not provided by Hoffman et al.

Daum (147) reported in 1986 another retrospective study on the effects of orthoptics in DEXT. He reported that the angle of deviation decreased at distance more than at near resulting in a decrease in the A/C/A ratio.

Heath & Hofstetter (148) had also reported in 1952 that the stimulus A/C/A decreased from 10/1 to 6/1 after training. Veaugn (149) in 1979 demonstrated that 30% of his patients who had significant exodeviation before therapy showed eso fixation disparity after therapy. Daum (147) in 1986 reported that both positive and negative fusional vergences and their respective recoveries increased after therapy.

Goldrich (141) reported (1980) improvement in ocular motility, accommodative facility, vergence range/flexibility and a decrease in suppression after therapy.

2. Occlusion:

Flyn et al reported in 1976 (150), that while treating amblyopic X(T)s with patching, they noted an improvement in sensory and motor fusion as determined by an elimination of the suppression scotoma; a reduction of the angle of deviation; and/ or improvement in fusional ranges. They studied 31 X(T)s who were alternately occluded full time for 6-12 weeks (average age 7.6 years, SD 3.3). The mean pretherapy distance deviation was 20° (±7.2°) and 15.4 diopters (±11.8°) at near.

Sixty-seven percent of the patients had an improvement in their sensory motor performance. In 22%, the deviation became almost phoric; fusion improved and all evidence of suppression on a synoptophore or in free space disappeared. The motor effect consisted of a reduction in the angle and/or a change from a tropia to a phoria. The most common sensory change was elimination of the suppression scotoma with a report of spontaneous diplopia.

Twelve patients, almost 33% of his sample, had a negative effect from patching, i.e., an increase in the size and character of the deviation. Flyn et al stated that it was impossible in retrospect to predict which children would respond negatively or positively to occlusion.

Velez (151) reported (in the same book) that he had evaluated 221 XT patients with deviations greater than 20° who had surgery and/or antisuppression techniques. He reported that antisuppression techniques did not affect his post-surgical results. Velez did not describe which antisuppression techniques were used, or how long or well they were used.
Chutter, an orthoptist, (152) (1977) also studied the effect of part-time occlusion on X(T). The dominant eye was initially patched for one week, then alternated. Fifty-one patients were treated: 28 simulated DEX(T), 12 convergence insufficiency type X(T), 4 true DEX(T), and 5 constant XTs. The patients ranged from 4-10 years of age.

Results indicated that patients patched for 3 to 8 hours a day every day did as well, if not better than, patients with full-time patching. Seventy-six percent improved in both groups. The average length of time of treatment was 6 weeks. Patients with deviations greater than 25° benefited from patching but ultimately needed surgery. Improvement consisted of a decrease in the size of deviation and an improvement in fusional ranges and recovery measurements.

Iacobucci & Henderson (153) (1965) used constant occlusion for periods up to three months on 17 X(T)s. Fifty-three percent had stronger fusion demonstrated by a change from an intermittent strabismus to a phoria.

Spoor & Hiles (154) (1979) in a prospective study of 38 young children (average age 29 months) with part-time occlusion showed that approximately 50% were changed from an intermittent strabismus to a phoria; approximately 10% became worse. The results were better when the deviation was under 20°.

Spoor & Hiles (155) also subsequently reported their long term results with occlusion by re-evaluating 34 of the original 38 patients who underwent occlusion therapy. The mean age at the beginning of the study was 2 years 5 months, while the mean duration of occlusion was 15 months. The mean age of their patients at the end of the study was 8 years 4 months. Of the initial 22 patients with good results, 18 were able to participate in the study. Fourteen of the 18 (78%) patients maintained a small esophoria after discontinuing occlusion therapy. The remaining four decompensated and underwent surgery.

They also reported the results of 14 patients who failed initial occlusion therapy and underwent surgery. They reported that excellent results were obtained. They felt that occlusion retarded the development of suppression and thus improved the development of fusional amplitudes.

Freeman & Isenberg (156) in 1989 presented a series of 11 early onset X(T)s treated with part-time occlusion for 4-6 hours per day (age 9 months to 5 years 2 months). All patients initially had some improvement. Three patients (27%) developed a constant XT and required surgery; another three remained phoric avoiding the need for surgery; and five continued to require intermittent patching to maintain their improved status. Similar findings were reported in slightly older children (age 17 months to 13 years) in a subsequent study (157).

3. Minus lens therapy:

Minus lenses have been used to stimulate accommodative-convergence in an attempt to reduce exodeviations. Results have been controversial.

Caltrider and Jampolsky (158) (1983) prescribed over correcting minus lenses (+2.0 to 4.00 D) for 35 children with X(T). Of these, 46% showed a change from a poorly controlled X(T) to a well controlled esophoria, 26° decreased their deviation by 15° while their deviation remained latent. Ten of the original 35 were followed for more than a year and 70% of those maintained their improved status of binocularity. The duration of minus lens therapy was from 2-15 months with the median being 18 months. The patients were slowly weaned off the minus lens therapy.

They also reported a decrease in the distance-near AC/A in 38% of the children wearing lenses. The greatest change occurred in those children who had the highest distance-near AC/A ratios. They noted that there was a significant change in the distance deviation while a minimal change occurred in the near deviation.

Though Caltrider & Jampolsky suggest that this represents a change in AC/A ratio, a simpler explanation would invoke the slow vergence system (vergence aftereffects). The esophoria generated at near would be initially eliminated by fusional divergence. However, over time, feedback from fusional divergence at near to the slow vergence system would result in relative orthophorization and reduction of the apparent AC/A ratio.

Iacobucci et al (159) (1986) reported treating with minus lenses 37 patients who were initially undercorrected surgically. Followup time was from 3-9 years. After an average of 24 months of followup, they classified 35% as "excellent", 16% as "satisfactory", and 46% as "poor". (Initially, 75% were classified as "poor"). Interestingly, they did not find any relationship between success with over minus lenses and AC/A ratios.

The reported long term success of (over) minus lens therapy is surprisingly good when one considers that most DE cases have a normal AC/A.

Rustein et al (160) (1989) evaluated the possibility that the minus lenses might result in an increase in myopia. They reported that there was no "statistically significant" difference in the development of myopia between their patient sample wearing minus lens overcorrection and the reported incidence of naturally occurring myopia.

4. Prism therapy:

Veronneau-Troutman et al (161) (1976) performed a retrospective study on 37 X(T)s (average age 8.5 years; range 2-26 years) who were prescribed prisms to correct their exodeviation. Some of the patients wore prisms only, while others had orthoptics and/or surgery.

They reported that some constant XTs became intermittent while others became phoric. They also observed convergence amplitudes improved with prismatic correction. They reported that 19% were "cured" with prisms alone. However, three cases increased their angle of exodeviation following the wearing of prisms. [Ed note: An early prism adaptation test?]

The amount of prism for NRC DEXT was XT + XT/2 while for ARC DEXT they overcorrected the deviation. The mean increase in convergence ranges was 8° without orthoptics and 10° with orthoptics.

Praat-Johnson & Tillson (162) (1979) reported that 8 of 12 patients with exodeviations smaller than 20°, who wore prisms which eliminated their deviation, were "cured" after wearing the prisms for 1 to 2 years. The patients' ages were between 2 and 8 years. On the other hand, those children who did not wear the prism glasses failed to show any improvement. The authors stated that it was difficult to get some of the children to wear their prism spectacles.

5. Biofeedback:

Auditory biofeedback using an infrared eye movement monitor has been described by Goklich (163) (1982). Using a variable pitched tone, Goklich provided auditory biofeedback for the postural sense of the eye. The goal of therapy was to use biofeedback to maintain normal alignment of the eyes in a non-visual environment, i.e., a darkened room, while the patient performed a non-visual task. He treated 12 XT patients (7 DEXTs, 3 basic XTs, and 2 constant XT).

Treatment took 8-18 hours for DEXT with 71% achieving "excellent" results. The
results were less encouraging with basic X(T)s. Therapy for basic X(T) took approximately 20 hours while only 33% were classified as "fair". One of the constant XTs achieved a cosmetic success while the other one failed. Abandor (164) reported a similar result using biofeedback.

6. Review and Summary of the Effectiveness of Orthoptics:

The orthoptic treatment success rates are impressive, especially when one considers that therapy was often carried out by clinic patients who were required to perform home-based therapy. (Our own experience is that home-based therapy is rarely performed, and if performed it is often done incorrectly).

The only study we found which failed to report any improvement with orthoptics was reported by Moore, an orthoptist (165) (1983). She performed diplopia awareness training for one month with concurrent fusional vergence training. Each patient attended only four in-office sessions which stressed suppression techniques. (There was no mention of methods to encourage or monitor compliance with techniques outside the office.) The duration of orthoptic therapy used in this study was briefer than any other study described.

According to France, an orthoptist (166) (1992), "orthoptic management is usually unsuccessful if undertaken as a substitute for surgery. However, it (orthoptics) has been shown to enhance surgical success in 60-67% of the cures". She cites various references (130, 153, 138, 212) to support this contention. However, the authors of only 4 of the 11 references which she cites do not consider orthoptics a primary treatment for X(T).

France also surveyed 150 orthoptists to determine their perceived role in the diagnosis and treatment of XT. All stated that they would treat a symptomatic esophoria, 95% would treat X(T)s, and 48% said they would treat constant XTs.

Orthoptist orthoptic therapy is primarily given to the patient to do at home while optometric orthoptic therapy utilizes both office and home therapy.

Therapy by orthoptists consists of "push-up" (near point of convergence) techniques with suppression controls, red filter techniques and occlusion for suppression, physiological diplopia, fusional vergence amplitude therapy, and passive orthoptics, (i.e., patching, overcorrecting minus lenses, and prisms).

France suggested that X(T) of less than 15s may be treated with orthoptics alone including occlusion, and in deviations over 25s orthoptics can be used as an adjunct to surgery.

Von Noorden (16) and Parks (35), both surgeons, have reviewed the success rate of orthoptic therapy for X(T) and have cited Moore's study (165) as "proof" that orthoptics is at best an equivocal method of treatment. However, over 20 studies cited above, using a variety of techniques, document the potential effectiveness of orthoptics.

Romano & Wilson (107) recently surveyed 104 selected senior and charter members of the American Association for Pediatric Ophthalmology and Strabismus (AAPOS) of which 65 replied. Half of the respondents queried rarely or never used orthoptics. Of the 52% who routinely used orthoptics, 88% used occlusion, 65% used minus lenses, 33% used prisms, 5% used sunglassess, and 27% used orthoptic exercises.

Duckman, an optometrist, (136) in his 1987 review of the efficacy of vision training for XT, combined orthoptic data for X(T) including vergence insufficiency type X(T) from 8 studies that included 615 patients.

He reported that the results of orthoptics in 62% of these 615 patients were classified as "good" or "excellent". If the studies which included convergence insufficiency type XT were excluded, then 184 of 291 (63%) DEX(T) cases could still be classified as "good" or "excellent".

Most of these retrospective studies were performed in a clinic environment and as such did not represent optimal conditions (as might be obtained in a scientific laboratory setting).

B. Surgery

1. History:

The first documented surgical treatment for strabismus occurred on October 26, 1839. It was performed by Johann Friedrich Dieffenbach, a general surgeon, who has become known as the Father of Plastic Surgery (168). Based on the method of performing a tenotomy on the achilles tendon in the club foot, he transected the medial rectus muscle tendon for the correction of "internal squat" (esotropia) (169).

Within a short period of time, he and others performed hundreds of ocular muscle tenomies on both medial and lateral rectus muscles. Over the next one hundred years, refinements in surgical technique occurred with tenotomy being abandoned and replaced with more accurate technique.

Any discussion of surgery must properly deal with three questions: 1) who to operate on, i.e., what clinical features of the strabismus does the patient have that require surgical intervention; 2) what specific surgical procedure should be performed; and 3) what is the criteria for a success or cure?

In general, surgical intervention is considered when non-surgical therapy is failing; there is a deterioration in binocularity manifested by increasing tropia position, squinting, photophobia and asthenopia; and/or there is parental or personal unhappiness when alternative therapies have not met expectations.

Once surgery has been decided upon, the surgeon must decide on the specific procedure. Dunnington (11) (1927) was the first to suggest that surgery should be performed only on the lateral rectus muscle for pure divergence excess XT. He recommended that open tenotomy be performed on one or both lateral recti, depending upon the size of the deviation. Dunnington's ideal postoperative position was an initial overcorrection of 15 "prism degrees".

However, free tenotomy soon lost favor due to its variable success and imprecise nature. Tenotomy was replaced by measured recession as the most effective method to weaken a muscle as originally described by Princo in 1887 (170), later refined by Jameson (171) (1922), and popularized at midcentury by Costenbader (12,172), then by Jampolsky (173), Knapp (174), Parks (175), Dunlap (64), and others over the next decade.

Costenbader used bilateral lateral rectus muscle recessions. He reported final overcorrections in two cases in 1950. This led Sugar (177) to advocate in 1956 that at least one recession of a medial rectus muscle should be done to prevent the development of a consecutive ET. (We believe these two cases might have been convergence insufficiency type XT).

Burian (10) in 1966 strongly advocated measured bilateral lateral rectus muscle recessions for true divergence excess.

In a recent survey conducted by Romano & Wilson (167) of charter and senior members of the AAPOS, the vast majority indicated that they performed bilateral lateral rectus muscle recessions for both DEXT and basic X(T). The amount of surgical recession was based primarily upon the distance measurement. The amount of surgery was calculated by
their own surgical guidelines or the surgical formula advocated by Parks (35).

Wide variation in surgical techniques of suture placement, surgical approaches and amounts of surgery performed may play a role in the wide variation of surgical success rates.

If the patient does not have a basic XT or a true DE type XT, but has another type of esodeviation such as convergence insufficiency or simulated DEXT, according to Kushner (41) (1986), von Noorden (178) (1976) and Hermann (179) (1981), alternative surgical procedures should be used.

If an A- or V-pattern exists, offsetting the horizontal recti superiorly or inferiorly will often decrease these patterns. The occurrence of vertical deviations is not uncommon as White et al (180) (1939) reported; 59.9% of his 1,955 patients had a vertical imbalance along with their divergence anomaly.

Lateral incomitance occurs in approximately 22% of XT patients according to Moore (65). But generally, altering the surgical approach to correct this incomitance has not been found to be necessary. Repta & Arnoldi (63) have suggested that prism measurement artifacts can be responsible for the apparent lateral incomitance. Thus true lateral incomitance is probably uncommon.

Let us now deal with the third question: what is a surgical success? Surgeons include a variety of postoperative results as "successful", e.g., a small angle ET or XT of 10° or less; a Monofixation Syndrome; or total elimination of the strabismus. A "cure", as defined by Pratt-Johnson in his recent 1992 publication (181), should meet the following criteria:

- No manifest tropia in any position of gaze or at any distance.
- No winking or closing of one eye in sunshine or bright lights.
- Stereocuity of at least 60 sec of arc on the Titmus Test at 16 inches.
- Normal vergence and divergent fusional amplitudes with diplopia when these are exceeded.
- Near point of convergence under 10 centimeters.
- Central fusion with non-suppression of central controls which subhend a visual angle less than 5° on slides in a haploscopic device such as the Troposcope or Synoptophore.

2. Intended immediate overcorrection:

Most strabismus surgeons today strive for an initial (in the first days to weeks) postoperative overcorrection to stabilize the long term results, as proposed by Cooper in 1966 (182) ("purposeful overcorrection"). Rab & Parks (183) (1969) and Jumpolsky (184) (1986) have suggested that this overcorrection should be 11-22°. Scott et al (185) (1978) recommended that the amount of overcorrection should be 4-14°. In 1927, Dunnington (11) had suggested 15 "prism degrees".

Some surgeons feel that using postoperative adjustable suture techniques may create more accurate surgical results with better long term stability.

Regarding intended overcorrection and postoperative adjustable sutures, McNeer (186) (1987) evaluated XT surgical results (all had bilateral lateral rectus muscle recessions) in three groups: 1) 25 non-adjustable suture patients; 2) 17 adjustable suture patients having an initial postoperative adjustment to 5-11° eso; and 3) 16 adjustable suture patients having an initial postoperative adjustment to 12-20° eso.

The 25 non-adjustable group 1 patients had average preoperative near deviation of 25°, an immediate postoperative deviation of 0°, a XT which increased to 4° after two years; 12 of the 25 had a recurrent XT. Patients in group 2 (18% had to be adjusted to place the patient in the proper range) had a near postoperative deviation of 7° eso which changed to 2° eso within 2 years. The patients in group 3 (60% needed postoperative suture adjustments to achieve this degree of overcorrection) had an initial mean postoperative deviation of 18° eso deviation which decreased to a mild eso within 2 years. Five of the sixteen in group 3 had a large esostrabismus, and one had a recurrent secondary XT.

Limited immediate postoperative diplopia has been thought to be therapeutic in eliminating suppression and stimulating fusional movement to allow for long term stability. Weston et al (187) (1991) and McNeer's studies (186) suggest that the best immediate postoperative position should be 5-6° eso.

Historically, according to Dunlap & Gaffney (188) (1933), the surgery was unable to predictively and constantly create a specific amount of postsurgical overcorrection. Cooper (182) (1968), attempted to produce a deliberate overcorrection. He was only able to achieve this goal in 37% of the cases he operated on. He divided his presurgical patients into two groups. In the first group he attempted to create exact surgical alignment, while in the second group he tried to create a deliberate overcorrection. His postoperative findings showed that there was no statistical difference between the groups. Von Noorden, in the most recent edition of his textbook (16), stated that the purposeful production of a small overcorrection only occurs by chance. However, if an overcorrection between 10-15° is achieved, one should expect an 80% chance of acceptable long term binocular motor alignment. The recent efforts of McNeer, Weston et al suggest that this is possible.

These findings suggest that factors other than simple motor alignment play a role in the ultimate success.

3. Early versus late surgery:

The question of early surgery vs late surgery was addressed by Pratt-Johnson et al in 1977 (189). They separated their surgical patients into two groups. One group was under the age of four years (39 patients, average age 2 1/2 yrs) and the other consisted of patients older than four years (61 patients, average age 5 1/2 yrs). Four patients were older than 7.

Results (their criteria for cure was that the deviation had to be less than 10° one year after surgery): in the under four age group 61% were cured, while only 28% achieved a cure in the over four age group. The overall cure rate was 41% with 81% being cosmetically corrected. Their study did not support the use of early postop overcorrection to effect a cure.

Ambyopia occurred in 4 patients who developed a consecutive esotropia in the under age four group.

[I]t is difficult to determine the results of any therapy in the young and non-communicative. Measurements and testing are often variable with unstable results. Young patients may not be able to respond to various sensory/motor tests. Thus, the determination of a cure in the young and non-communicative, with any form of treatment, suffers from measurement error.

Some postsurgical XT patients have improved fusion control with a diminution of the deviation. Although not ideal, it is an improvement with which prismatic therapy, or minus lenses, may allow the deviation to stabilize for a long period of time. Further surgery, if necessary, may always be performed.

Prolonged overcorrection in the very young has the possibility of dire binocular consequence, i.e., amblyopia and/or loss of stereopsis (see Pratt-Johnson (189) above). Edelmann et al (190) reported in 1988 that 5 of 24 children (21%) operated upon for
XT between the ages of 2 and 4 years, developed a consecutive esotropia requiring surgery. Twenty-nine percent of them had a reduction of stereocuity. Nine percent of those who had XT surgery between 4-6 years of age developed amblyopia and 20% of these had a reduction in stereocuity. However, after age 6 years no child developed amblyopia or lost stereocuity.

Richards & Parks (191) noted in 1983 that 12% of patients under 3 years of age were (finally) overcorrected while only 3% over 3 years were (finally) overcorrected.

Care must be exercised in balancing the desire for a "real cure" apparently more readily achieved with early surgery versus the potential complications of microtropia, amblyopia and loss of stereocuity in the young, visually developing child.

Von Noorden (16) recommends that surgery be delayed until at least 4 years of age. Prior to age 4, binocular vision can be reinforced with minus lenses, patching, base in prisms and TV trainers. He has noted that surgical correction for deviations greater than 20° rarely results in a consecutive esotropia.

4. Management of consecutive esotropia:

At some point in time, the aforementioned desirable intended purposeful immediate and early postoperative esodiverging overcorrection becomes no longer acceptable. This is usually around three to four weeks postop. This esodivergence then becomes (or is redefined to be) a consecutive esotropia.

Consecutive esotropia which occurs in 6-20% of surgically treated XT's (192-194) may be initially handled by either judicious observation or the application of base out prisms. If the esodivergence does not change after a few additional weeks, some groups advocate limited alternate patching.

The amount of prism should be the least amount which eliminates the deviation in all gazes at both distance and near. Thin plastic press-on Fresnel prisms are advantageous when large amounts of prism are used and/or when frequent changes are made. However, they have more chromatic aberration and thus reduce vision more than "ground-in" full thickness glass prisms.

Anicholinesterase miotics and/or bifocals may also be useful here.

The goal is to stimulate slow vergence to reduce the apparent deviation, by slowly reducing the miotics, bifocals, or prism (2 to 5° at a time). Orthoptics designed to improve convergence may be helpful in stimulating fusional vergence and slow vergence. The elimination of prism with orthoptic therapy is a slow process and requires good patient, parent, physician rapport.

If no change occurs within approximately 6 months, an (additional) surgical procedure may be indicated. This is usually bilateral medial rectus muscle recession or a recession–resection on one eye depending on the clinical findings. According to Moore et al (65), 61% who developed a consecutive esotropia required such additional ET surgery (or by calculation, approximately 5-10% of all patients undergoing XT surgery).

5. Bilateral lateral rectus recession versus recession–resections for the initial XT surgery:

Burian (195) (1958) stated that different surgical procedures should be performed on true DEXT and simulated DEXT basic XT. For true DEXT, he advocated recession of the lateral recti, while for simulated DEXT and basic XT he advocated monocular recession of the lateral rectus and resection of the medial rectus in the non-dominant eye ("recess–resect"). Burian believed that a bilateral lateral recurrerexsection resulted in a greater reduction in the distance exodeviation than the near, while recess–resect procedures were more apt to result in an equal correction at distance and near.

Von Noorden (39)(1969), evaluated Burian’s hypothesis. He compared results in two surgical groups: one in which both simulated and true DEXT received bilateral lateral rectus recessions; while the second group of simulated and true DEXT was subdivided for surgery according to Burian. In this group 70% were simulated DEXT and were surgically treated by Burian’s criteria with "recess–resect", while the other 30% were diagnosed as true DEXT and had bilateral lateral rectus recessions.

Table II below is a summary of von Noorden's data. The data indicate that the surgical success rate improves when true DEXTs have bilateral rectus recessions and simulated DEXTs have unilateral recess–resect, confirming Burian’s hypothesis.

<table>
<thead>
<tr>
<th>Group 1</th>
<th>Group 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recess LROU</td>
<td>Recess–Resect</td>
</tr>
<tr>
<td>Cure</td>
<td>44%</td>
</tr>
<tr>
<td>Improvement</td>
<td>20%</td>
</tr>
<tr>
<td>No change</td>
<td>20%</td>
</tr>
<tr>
<td>Overcorrection</td>
<td>16%</td>
</tr>
<tr>
<td>2nd Procedure</td>
<td>18%</td>
</tr>
</tbody>
</table>

* von Noorden GK. Divergence excess and simulated divergence: Diagnosis and surgical management. Ophthalmologica 1969;26:719-728
TABLE III:
Commonly Used Surgical Dosage Values for Bilateral Lateral Rectus Recessions (in mm) for Exotropia

<table>
<thead>
<tr>
<th>Exodeviation (α)</th>
<th>Parks &amp; Mitchell*</th>
<th>AAPOS Survey**</th>
</tr>
</thead>
<tbody>
<tr>
<td>15°</td>
<td>4 mm</td>
<td>4 mm</td>
</tr>
<tr>
<td>20</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>25</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>30</td>
<td>7</td>
<td>6.5</td>
</tr>
<tr>
<td>35</td>
<td>7.5</td>
<td>7</td>
</tr>
<tr>
<td>40</td>
<td>8</td>
<td>7.5</td>
</tr>
<tr>
<td>45</td>
<td>-</td>
<td>8</td>
</tr>
<tr>
<td>50</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>60</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>70</td>
<td>11</td>
<td>-</td>
</tr>
</tbody>
</table>


6. Variance in surgical results:
Scott et al (199) in 1975 attempted to quantify the specific factors which contribute to the variability of exotropia surgery results. They found the preoperative deviation itself accounted for only 36% of the total variance. The difference between near and distance deviations, age at time of surgery, refractive spherical equivalent, change in deviation in vertical gaze, and the initial preop measurement accounted for 94% of the variance.

Table IV, next page, provides the formula determined by Scott et al for bilateral lateral rectus recession.

They also reported that bilateral lateral rectus recessions provided a more stable post-operative condition, i.e., an average postoperative drift of 1.0° ±1.4 for lateral rectus recessions versus an average of 5.0° ±1.0 for the recess-resect group.

They reported that during the first 6 postoperative weeks there was a substantial shift in the deviation towards XT. This stabilized at the 6 week mark and remained fairly stable for their 2 year followup period.

Initial postoperative overcorrections greater than 15° resulted in a 70% alignment within ±9°, overcorrection between 4-14° resulted in a 81% normal binocular alignment result, while initial postoperative orthophoria resulted in only a 65% normal alignment rate 2 years after surgery. These findings also support the aforementioned desirability of an initial postoperative overcorrection.

7. Exotropia in older patients:
Schlossman et al (200) in 1985 evaluated the surgical management of X(T) in
TABLE IV:
Scott A., Marsh and Jampolsky's* Linear Regression Calculation of the Amount of Surgery for Bilateral Lateral Rectus Recession for Exotropia

<table>
<thead>
<tr>
<th>Mean partial regression coefficient in effect per unit</th>
<th>Patients measure. Example</th>
<th>Total change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preop' deviation (α)</td>
<td>.0544 X</td>
<td>35</td>
</tr>
<tr>
<td>Difference bet dist &amp; near measure (α)</td>
<td>.0164 X</td>
<td>10</td>
</tr>
<tr>
<td>Age (yrs) at surgery</td>
<td>-.0692 X</td>
<td>6.5 yrs</td>
</tr>
<tr>
<td>Refractive spherical equivalent (D)</td>
<td>.0473 X</td>
<td>+1.00</td>
</tr>
<tr>
<td>Change in deviation in upgaze (α)</td>
<td>.0071 X</td>
<td>0</td>
</tr>
<tr>
<td>Change in deviation in downgaze (α)</td>
<td>.0199 X</td>
<td>0</td>
</tr>
<tr>
<td>Mean change per mm of recession</td>
<td>1.0490</td>
<td></td>
</tr>
<tr>
<td>(constant derived by Scott et al)</td>
<td>Effect per mm</td>
<td></td>
</tr>
</tbody>
</table>

final calculation of surgery:
mm recession per lateral rectus = \( \frac{\text{Preop' deviation}}{2 \times \text{effect per mm}} \) = \( \frac{35}{2 \times 2.7160} \) = 6.5 mm recession for each LR


the older population. They evaluated 44 exotropic patients aged 15-70 years, whose presenting symptoms were asthenopia (33%), diplopia (29%), difficulty reading (20%), headaches (20%), and cosmesis (7%). They performed a recess-resect on 39 patients. Their findings indicate that overcorrection often resulted in diplopia in this age group. Therefore, they advocated deliberate undercorrection in this age group. They reported 29 of the 39 had significant improvement, i.e., deviation less than 15° and a reduction of symptoms. The older a patient becomes, the more ingrained the habitual visual-motor relationship. This relationship should not be altered. Thus it is wiser to leave an adult exotropic patient on the eso side postoperatively rather than on the eso side.
8. Review and Summary of the Effectiveness of Surgery:

A comprehensive historical literature review of surgical correction for DEXT was conducted and reported in an opometric journal in 1985 by two optometrists Flax & Selenow (201).

They reviewed all XT surgical papers published from 1953 to December 1982. They eliminated from their review all papers which did not provide what they felt were clear or adequate presurgical and postsurgical results, adequate criteria for success. They also eliminated all papers where orthoptics were used in combination with surgery.

They located 22 papers which met their criteria cited above. This included reports on 1,490 patients.

Five studies reported analysis of binocular functional data and are reported in the top section of Tables V & VI, next page.

Of the 571 patients included in these five studies, 34% were functionally successful ("cured"), 27% were motorically aligned, and 16% were cosmetically acceptable. The aggregate cosmetic success (within 15°) was 78%, with less than half having good binocular vision postsurgically.

The 17 other studies provided incomplete postoperative fusion and/or sensory measurements which were insufficient to determine functional success according to the authors. These 17 studies contained the remaining 919 patients, in 42% surgery eliminated their strabismus and an additional 16% were cosmetically acceptable. According to Flax & Selenow's calculations, 18% were worse or no better after exotropia surgery.

One difficulty interpreting this work by Flax and Selenow results from their attempt to compare a variety of surgical result grading systems, and the lack of a specific criteria for cure. For example, a residual postoperative exodeviation of 10° might be interpreted as a failure by these authors. Such a result, however, is often a satisfactory goal of surgery since a subsequent cure may occur without further specific therapy.

A second and larger problem occurs when one uses this information to compare surgical and non-surgical results: Surgery is usually performed on larger exodeviations and especially those that occur at an earlier age. These patients may not be amenable to intensive orthoptic therapy. Those XTs who receive surgery for their XT most likely are a different population from those XTs who receive orthoptic non-surgical therapy.

Comparison of treatment effectiveness cannot be made if the disease treated is not the same in two patient groups but is instead yet another independent variable.

Furthermore, much of the surgery reviewed was carried out between 10 and 40 years ago and techniques, training and knowledge have improved considerably over those years. Nor does the exclusion of cases which received orthoptics at some point help to illuminate an examination of treatment; some of the best results in surgical exotropia treatment may well have occurred in this subgroup excluded by Flax and Selenow. This group needs to be examined if only for purposes of comparison.

Hardesty et al (208) (1978) had the lowest treatment failure rate (14%) of contemporary reports published in a major refereed ophthalmic journal and for this distinction their work warrants further examination.

They performed a retrospective study on 100 consecutive X(T)s treated with bilateral lateral rectus recessions. The average followup period was 6 years. Overcorrections for more than two weeks were handled with miotics and correction of hyperopia when present. If this failed, alternate patching was employed. If patching was ineffective after 3-4 weeks, base out prisms equal to or greater than the angle of deviation were prescribed. The goal was to gradually reduce the prisms until they could be eliminated. Most patients with less than 15° of consecutive ET were "cured" with prism therapy. Patients not corrected with these procedures had surgery six months or more after the initial procedure.

Patients initially undercorrected were given base in prism equal to the deviation to provide constant binocular stimulation. Additionally, orthoptic exercises which improved fusional amplitudes and eliminated suppression were prescribed. Further surgery (bilateral medial rectus resection) was delayed for at least 6 months.

With these aggressive techniques, 78% of their patients achieved a functional cure (which meant no tropia at any distance, no verbal report of strabismus, and stereopsis of at least 400 sec of arc); 91% showed improvement or cure; and 9% were either not improved or worse.

Approximately one half of their X(T)s were successfully treated with one surgical procedure; the other half had a persistent over- or undercorrection which often required a second procedure.

They believed that their high surgical success rate was a result of immediately correcting any over- or undercorrection with prisms in order to maintain constant binocularity. Children old enough to cooperate were given orthoptics. Their therapeutic regimen differed from many other surgical studies in the aggressive use of prisms, orthoptics, and a second corrective surgical procedure as necessary to achieve a cure.

Mims & Wood (215) performed a retrospective study to determine the effective of preoperative alternate day patching on surgical results. Their patients were divided into three groups: 5-12 weeks of alternate all day occlusion, unilateral patching, and no patching.

Postoperative success was greater with both alternate day patching and unilateral patching (87% success) versus no patching (53% success). Their results indicate that alternate day patching significantly improved their surgical results. They point out the need for a controlled prospective study.

Since the publication of the Flax and Selenow review, Zibrandtsen et al (216) in 1986 reported a long term followup retrospective study on 25 X(T)s who had had surgery 10 or more years earlier. Of these patients 13/25 (52%) were phoric with good sensory function; 8/25 (32%) were classified as "fair"; and 4/25 (16%) were classified as "poor".

Differences between the Hardesty and the Zibbrandtsen groups may be accounted for by the use of prisms, patching, supplementary orthoptics, and/or different population characteristics.
### TABLE V:

Reports of Surgical Success in X(T) as Selectively Reviewed and Analyzed (see text) by Flax and Selenow*

(Studies listed in alphabetical order, 1-5 in the top first section provide sufficient data to analyze success by functional cure while studies 6-23 in the lower section present only enough data to analyze the results by motor alignment; cosmetic success (residual deviation less than 15°); and unsuccessful (no improvement or worse)).

<table>
<thead>
<tr>
<th>Study (reference #)</th>
<th># Cases</th>
<th>Functional Cure</th>
<th>Satisfactory Alignment</th>
<th>Cosmetically Acceptable</th>
<th>Unsuccessful</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooper/Leyman (135)</td>
<td>264</td>
<td>110</td>
<td>109</td>
<td>---</td>
<td>45</td>
</tr>
<tr>
<td>Dunlap/Gaffney (188)</td>
<td>100</td>
<td>12</td>
<td>21</td>
<td>24</td>
<td>43</td>
</tr>
<tr>
<td>Folk (202)</td>
<td>50</td>
<td>14</td>
<td>27</td>
<td>---</td>
<td>9</td>
</tr>
<tr>
<td>Moore (165)</td>
<td>57</td>
<td>19</td>
<td>---</td>
<td>29</td>
<td>9</td>
</tr>
<tr>
<td>Pratt-Johnson (181)</td>
<td>100</td>
<td>41</td>
<td>---</td>
<td>40</td>
<td>19</td>
</tr>
<tr>
<td><strong>SubTotal:</strong></td>
<td>571</td>
<td>196 (34.3%)</td>
<td>157 (27.5%)</td>
<td>93 (16.3%)</td>
<td>125 (21.9%)</td>
</tr>
<tr>
<td>Ballen (203)</td>
<td>16</td>
<td>---</td>
<td>12</td>
<td>---</td>
<td>4</td>
</tr>
<tr>
<td>Bedrossian (104)</td>
<td>35</td>
<td>---</td>
<td>24</td>
<td>---</td>
<td>11</td>
</tr>
<tr>
<td>Burian/Spivey (122)</td>
<td>98</td>
<td>---</td>
<td>54</td>
<td>---</td>
<td>44</td>
</tr>
<tr>
<td>Clark/Noel (205)</td>
<td>78</td>
<td>---</td>
<td>33</td>
<td>---</td>
<td>45</td>
</tr>
<tr>
<td>Fletcher/Silverman (206)</td>
<td>60</td>
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<td>45</td>
<td>---</td>
<td>15</td>
</tr>
<tr>
<td>Gillies</td>
<td>92</td>
<td>---</td>
<td>24</td>
<td>---</td>
<td>68</td>
</tr>
<tr>
<td>Hamptil/Place (207)</td>
<td>9</td>
<td>---</td>
<td>7</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Hardesty et al (208)</td>
<td>50</td>
<td>---</td>
<td>39</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Johnson (209)</td>
<td>51</td>
<td>---</td>
<td>25</td>
<td>20</td>
<td>6</td>
</tr>
<tr>
<td>Mulberger/McDonald (210)</td>
<td>25</td>
<td>---</td>
<td>8</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Mumma (211)</td>
<td>95</td>
<td>---</td>
<td>30</td>
<td>23</td>
<td>42</td>
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<tr>
<td>Newman/Mazow (212)</td>
<td>30</td>
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<td>---</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Raab/Parks (183)</td>
<td>93</td>
<td>---</td>
<td>---</td>
<td>51</td>
<td>42</td>
</tr>
<tr>
<td>Swan (213)</td>
<td>25</td>
<td>---</td>
<td>6</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Velez (151)</td>
<td>34</td>
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<td>14</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>von Noorden (16)</td>
<td>91</td>
<td>---</td>
<td>48</td>
<td>---</td>
<td>43</td>
</tr>
<tr>
<td>Windsor (214)</td>
<td>37</td>
<td>---</td>
<td>17</td>
<td>---</td>
<td>20</td>
</tr>
<tr>
<td><strong>SubTotal:</strong></td>
<td>919</td>
<td>---</td>
<td>386 (42.0%)</td>
<td>145 (15.8%)</td>
<td>388 (42.2%)</td>
</tr>
</tbody>
</table>

### TABLE VI: (ident Table V rearranged in chronological order with data converted to % rates)

**Reports of Surgical Success in X(T) as SelectivelyReviewed and Analyzed (see text) by Flax and Selenow***

(Studies listed in chronological order, 1-5 in the top first section provide sufficient data to analyze success by functional cure while studies 6-23 in the lower section present only enough data to analyze the results by motor alignment; cosmetic success (residual deviation less than 15°); and unsuccessful (no improvement or worse)).

<table>
<thead>
<tr>
<th>Year</th>
<th>Study (reference #)</th>
<th># Cases</th>
<th>Functional Cure %</th>
<th>Satisfactory Alignment %</th>
<th>Cosmetically Acceptable %</th>
<th>Unsuccessful %</th>
</tr>
</thead>
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<tr>
<td>1956</td>
<td>Folk (202)</td>
<td>50</td>
<td>28</td>
<td>54</td>
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<td>18</td>
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<tr>
<td>1963</td>
<td>Dunlap/Gaffney (188)</td>
<td>100</td>
<td>12</td>
<td>21</td>
<td>24</td>
<td>43</td>
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<tr>
<td>1963</td>
<td>Moore (165)</td>
<td>57</td>
<td>33</td>
<td>---</td>
<td>51</td>
<td>16</td>
</tr>
<tr>
<td>1976</td>
<td>Cooper/Leyman (135)</td>
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<td>42</td>
<td>41</td>
<td>---</td>
<td>17</td>
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<tr>
<td>1977</td>
<td>Pratt-Johnson (181)</td>
<td>100</td>
<td>41</td>
<td>---</td>
<td>40</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td><strong>SubTotal:</strong></td>
<td><strong>571</strong></td>
<td><strong>34.3%</strong></td>
<td><strong>27.5%</strong></td>
<td><strong>16.3%</strong></td>
<td><strong>21.9%</strong></td>
</tr>
<tr>
<td>1954</td>
<td>Mulberger/McDonald (210)</td>
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<td>32</td>
<td>28</td>
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<td>1958</td>
<td>Johnson (209)</td>
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<td>49</td>
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<td>12</td>
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<td>1960</td>
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<td>---</td>
<td>24</td>
<td>36</td>
<td>40</td>
</tr>
<tr>
<td>1962</td>
<td>Bedrossian (104)</td>
<td>35</td>
<td>---</td>
<td>69</td>
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<tr>
<td>1965</td>
<td>Burian/Spivey (122)</td>
<td>98</td>
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<tr>
<td>1966</td>
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<tr>
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<tr>
<td>1970</td>
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<td>1971</td>
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<td>1975</td>
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<td>41</td>
<td>26</td>
<td>32</td>
</tr>
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<td>1978</td>
<td>Hampwik/Place (207)</td>
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<td>Hardesty et al (208)</td>
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<td>1981</td>
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<td>---</td>
<td>42</td>
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<td>58</td>
</tr>
<tr>
<td>1981</td>
<td>Newman/Mazow (212)</td>
<td>30</td>
<td>---</td>
<td>---</td>
<td>67</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td><strong>SubTotal:</strong></td>
<td><strong>919</strong></td>
<td><strong>42.0%</strong></td>
<td><strong>15.8%</strong></td>
<td><strong>422%</strong></td>
<td></td>
</tr>
</tbody>
</table>

therapy did not use scaled questionnaires. Also, methods of evaluating intermixity are questionable or nonexistent.

Comparison across studies is difficult since populations vary. Also, specific surgical and orthoptic techniques vary with the eye health care professional.

It would be valuable to have a large scale prospective clinical trial to determine scientifically the best treatments for DEX(T). This review, if nothing else, would underline this need.

It is our impression that X(T) under the age of six years should be treated cautiously so as to reduce or eliminate the possibility of developing amblyopia or permanent loss of stereopsis.

- Patching, to eliminate or alter suppression patterns should be done with caution, since patching might change a small angle X(T) into a large angle XT.
- Minus lens therapy might be initiated with or without prisms to eliminate any evidence of deviation.
- A red lens and TV trainer could be used 1-2 hours a day in an attempt to eliminate the suppression scotoma.
- If the deviation persists or increases, surgical intervention should be considered.

In children over six years, some professionals believe that orthoptics or vision training should be instituted if the deviation is not too large. Large deviations, however, may be initially treated with surgery unless the patient or parents or the eye care professional want to try nonsurgical means first.

An orthoptic approach suggested and used by the first author includes office based therapy and home therapy using the following modalities: red lens techniques, minus lenses, prisms, stereoscopic targets in space to initiate alignment and stereoscopic appreciation. Stereoscopic detail is then slowly faded out until only flat fusion targets remain. Alignment is then reinforced while viewing non-fusible targets, e.g., simultaneous perception targets.

If no improvement or deterioration is seen within a reasonable period, surgery should be considered. The specific surgical procedure remains the choice of the surgeon since no specific advantage has been shown to accrue to any specific technique, although bilateral lateral rectus resections seem to be almost universally the first procedure for most North American eye muscle surgeons. An attempt to surgically create a moderate early postoperative esotropia of 10° should made, if possible, in the young.

Adults and children over 12 years of age may be treated similarly. Generally, if presented with a large deviation, surgery to reduce the strabismus (conservative so as not to create an esotropia postoperatively in this group) followed by orthoptics is usually rewarding.

If there are any cases with clear indications for one choice of therapy over another, it would seem that very large exodeviations in infants and toddlers would be good candidates for primary surgical treatment because orthoptic therapy is not applicable or practical or very successful in such cases because of both the size of the deviation and limited cooperation available from preverbal children. (But see the aforementioned hazards to binocularity).

Conversely, older children and adults, in whom orthoptic measures can be used, especially those with smaller deviations more readily controllable by feedback, patching, lenses or prisms, would seem the best candidates for primary non-surgical treatment.

Between these examples, active and passive orthoptics and surgery can be justified, individually or together.

V. CONCLUSION

We have reviewed both divergence excess and basic exotropia which have similar sensory motor characteristics.

Treatment modalities include minus lenses, prisms, orthoptics, and/or surgery. Each therapeutic regimen has its proponents. To date no uniformly accepted treatment plan has been acceptable to all of the eye care professional community who treat these problems. The lack of agreement among professionals as to the proper treatment suggests the difficulty in creating a permanent perfect cure.

Lastly, we agree with Baker (217), who suggests that future treatment of exotropia "must consider that the control center for ocular motility is located in the theoretical black box". Treatment of the strabismus must be aimed not only at controlling the sensory motor components, but also their interactions.

Key Words
- exotropia, basic exotropia, divergence excess
- exotropia, intermittent orthoptics
- prism adaptation
- review, major surgery, strabismus
- vergence after effects
- vision training
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