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Intermittent Exotropia: Stimulus Characteristics Affect Tests for Retinal Correspondence and Suppression

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ABSTRACT: ***Background and Purpose:*** Prior studies have reported various sensory responses in subjects with intermittent exotropia [X(T)]. These varying responses have been proposed due to differences in stimulus targets, backgrounds, or even a lack of control of binocular alignment. This study investigated the effects of varying target and background stimuli while controlling binocular alignment.

Methods: Eight X(T)s of the divergence excess or basic type were presented dichoptic computer generated visual stimuli while an infra red eye movement monitoring system determined horizontal eye position of each eye. Target and background were varied to assess their effect on sensory responses during latent and manifest exotropia.

Results: Most of our X(T)s demonstrated, while tropic, a consistent, i.e., dominant, type of retinal correspondence, i.e. a response that occurred on most tests, independent of the stimulus or background used for testing. Four subjects demonstrated harmonious anomalous retinal correspondence (HARC) while three subjects demonstrated normal retinal correspondence (NRC) with three out of four of the tests. In two out of four stimuli used for testing, one subject demonstrated NRC and another HARC.

Conclusions: Complex backgrounds resulted in the largest number of suppressions, whereas blank backgrounds decreased the number of reported suppressions.

Key words: binocular vision; exotropia, divergence excess; exotropia, intermittent; retinal correspondence; sensory adaptations to strabismus; strabismus; suppression

Translations of this abstract into Spanish, French and German are on the next page.

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Abstract translated into Spanish, French, and German

Exotropia Intermitente: Las Características de los Estímulos Afectan las Pruebas para correspondencia Retinal y Supresión

*RESUMEN: **Antecedentes y Propósito:** Estudios previos han reportado diversas respuestas variable han sido debidas a las diferencias en los objetos de estímulo, del contorno, o aún por falta de control del alineamiento visual. En este estudio se investigaron los efectos de los objetos de estímulo cambiantes y del contorno mientras se controlaba el alineamiento binocular.*

***Métodos:** Ocho X(T)s del tipo de exceso de divergencia o básica se les presentaron estímulos visuales dicópticos generados por computadora mientras se determinaba la posición horizontal de cada ojo mediante un sistema infrarrojo de monitoreo de movimiento ocular. El estímulo y el contorno fueron variados para tasar el efecto de las respuestas sensoriales durante la exotropia latente y manifiesta.*

***Resultados:** La mayoría de nuestras X(T)s demostraron, que mientras estaben en tropia, una dominancia consistente del tipo de correspondencia retinal, respuesta que se presentó con la mayoría de las pruebas, independientemente de los estímulos o del contorno usados. Cuatro sujetos demostraron correspondencia retinal anómala armónica (CRAA) mientras que tres sujetos demostraron correspondencia retinal normal (CRN) en tres de las cuatro pruebas. Con dos de los cuatro estímulos usados para efectuar las pruebas, uno sujeto demostró CRN y otro demostró CRAA.*

***Conclusiones:** Con los contornos complejos se encontraron el mayor número de casos con supresión, mientras que con los contornos blancos disminuyeron los casos con supresión.*

Exotropie intermittente: les caractéristiques du stimulus influençant les tests pour la correspondance rétinienne et la suppression.

RESUME: Fondement et but: Des études antérieures ont fait état de la variation des réponses sensorielles chez des sujets présentant une exotropie intermittente (X(t)). On a pensé que la variation de ces réponses était due aux caractères différents des cibles pour stimuler, des arrière - plans ou même au manque de contrôle de l'alignement binoculaire. Cette étude se propose d'étudier les effets des stimuli quand on modifie la cible et l'arrière plan mais avec un contrôle de l'alignement binoculaire.

Méthodes: Huit sujets présentant une X(t) de type excès de divergence, ou de type basique étaient soumis à des stimulations visuelles générées par un computer dichoptic Parallèlement un système infra rouge de contrôle des mouvements des yeux déterminait la position de chaque oeil dans le plan horizontal. On faisait varier la cible et l'arrière plan afin de voir les effets sur les réponses sensorielles quand l'exotropie était latente ou manifeste.

Résultats: La plupart de nos sujets ayant une X(t) présentaient quand ils étaient tropiques, un type de correspondance rétinienne identique, c'est à dire dominante, se caractérisant par une réponse, qui pour la plupart des tests, était indépendante du stimulus ou de l'arrière plan utilisé pour l'examen. Quatre sujets avaient une correspondance rétinienne anormale harmonieuse (HARC) alors que trois sujets avaient une correspondance rétinienne normale (NRC) pour trois des quatre tests. Pour deux des quatre stimuli utilisés pour tester, un sujet avait une NRC et un autre une HARC.

Conclusions: Des arriére-plans complexes entraînent le plus souvent des suppressions, alors que des arriére-plans unis entraînent une réduction du nombre des cas de suppression.

Intermittierende Exotropie: Stimuluseigenschaften beeinflussen retinale Korrespondenztests und Suppression

ZUSAMMENFASSUNG: Hintergrund und Zielsetzung: In früheren Studien wurde gezeigt, dass Patienten mit intermittierender Exotropia (X(T)) unterschiedliche sensorische Antworten zeigten. Diese Unterschiede wurden auf differente Zielstimuli, Hintergründe, oder sogar auf fehlende Kontrolle des Geradestandes, zurückgeführt. In dieser Studie wurden die Effekte unterschiedlicher Ziel- und Hintergrundreize unter Kontrolle de Augenstellung untersucht.

Methoden: Acht intermittierend exotropen Patienten vom Neutral- oder Divergenzexzesstyp wurden dichotopische, computergenerierte visuelle Reize angeboten, während mit einem auf Infrerotbasis arbeitenden Augenbewegungskontrollsystem die horizontale Position beider Augen bestimmt wurde. Das Ziel und der Hintergrund wurden verändert, um ihren Effekt auf sensorische Antworten während kompensierter und manifester Schielphasen zu untersuchen.

Ergebnisse: Die meisten unserer intermittierend exotropen Patienten zeigten während der Schielphase eine konsistente, d.h. dominante Art der retinalen Korrespondenz, d.h. ein antwortverhalten, das bei den meisten Tests auftrat unabhängig vom Stimulus oder Hintergrund, der für den Test benutzi wurde. Vier Personen zeigten harmonisch anomale retinale Korrespondenz (HARC). Drei Patienten zeigten normale retinale Korrespondenz (NRC) in drei der vier Test. Bei zwei der vier benutzten Reize zeigte ein Patient NRC und ein anderer HARC.

Schlussfolgerung: Komplexe Hintergrundmuster führen in den meisten Fällen zur suppression, während homogene Hintergründe die Häufigkeit der suppression verminderte.

INTRODUCTION

When intermittent exotropes (X(T)s) of the divergence excess (DE) or basic type are binocularly aligned, (non-strabismic) normal sensory findings such as 40 arc seconds of stereoacuity, bifoveal fixation and normal retinal correspondence are found (1). Any suppression that occurs during orthotropic alignment has been postulated to be stimulus mediated. It most commonly occurs during dichoptic viewing of first degree fusion targets and during measurements of physiological diplopia (2).

When an X(T) is in the deviated position (exotropic), variable findings have been reported. These include: normal retinal correspondence (NRC); harmonious anomalous retinal correspondence (HARC); unharmonious anomalous retinal correspondence (UARC); or lack of retinal correspondence (3-16). Furthermore, each of these states of sensory binocular cooperation has been associated with regional retinal suppression of variable size and depth.

Travers (14) dissociated the eyes by using two tangent screens placed at right angles to each other with a mirror positioned at 45 degrees placed in front of one eye. Then retinal suppression areas and zones were plotted by moving a non- luminous target across the screen and performing binocular perimetry with anaglyphs. He found two suppression areas in the deviating eye, one corresponding to the fovea of the deviating eye which he named "the confusion point," and the other at the diplopia point.

Jampolsky (15), using a Risley prism and a red glass, reported that DEX(T)s had hemiretinal temporal suppression occurring only during deviation. He also found suppression zones which extended from the fovea of the deviating eye into the temporal retina to the diplopia point. When targets of similar form and/or contour were used, larger suppression zones were measured. He postulated that suppression was related to the form and contour of the stimuli, rather than to the size, color, or illumination of the targets.

Pratt-Johnson & Wee (3) used three methods to measure suppression and retinal correspondence in X(T)s.

-The first method employed red/green anaglyph glasses and fixation on a red button while a green light was projected.

-The second method utilized a Lees screen in which a mirror was placed at a 45 degree angle while binocular perimetry was performed. Eye position and binocular alignment (tropia) were monitored by tagging the deviating fovea with an afterimage.

-The third method used polarizing glasses and targets for dissociation and dichoptic testing.

They found two dense suppression scotomas, one at or about the fovea and the other at the diplopia point.

In addition, they reported non-suppressed temporal retina with HARC. During testing with polarizing lenses the temporal retinal suppression area increased. They suggested that viewing with the polarizing lenses created a "more complex visual environment" resulting in greater suppression.

Awaya & colleagues (4) measured suppression in XTs using the Aulhorn phase difference haploscope with and without a fusional background. Subjects reported suppression scotomas at the fovea and/or diplopia point with targets which contained a fusible background. However, when stimuli without a fusible background were presented, only a foveal suppression scotoma was reported - none were observed at the diplopia point. They concluded that X(T)s have NRC with suppression.

Melek & co-workers (5) performed binocular Goldmann perimetry with intermittent exotropic subjects while they wore Bagolini's Striated Glasses. The binocular visual field was measured during both the aligned and the deviated positions. Two types of suppressions were found during deviation:
1. temporal retinal suppression in one or both eyes; or
2. suppression scotomas at both the diplopia and foveal points, with a sector of peripheral temporal retina suppressed as well. NRC was found to be present in all the non-suppressed retinal zones.

Bielschowsky (6) was the first to report ARC in X(T)s. He reported a cross on afterimage testing when the eyes were straight (NRC) and separation of the afterimages equal to the angle of deviation during deviation (=HARC). Burian (7) explained this phenomenon by noting that suppression did not occur when the eyes were binocularly aligned, but occurred "when the deviating eye turned out... resulting in a simultaneous displacement of the egocentric localization of all visual directions of the eye so that no diplopia occurs". He called this ARC.

Bagolini (8) measured the sensory state of manifest DEX(T) using his Bagolini graded filter bar and his Striated Glasses. He found half of the subjects tested showed HARC with horopters which did not differ significantly from those subjects displaying NRC.

Boucher (9), using the method of common visual directions, measured the horopter on an X(T) during deviation. He found the horopter shape similar to a subject with NRC.

Campos (10), using Bagolini Striated Glasses and non-dissociating mirrors, reported that most DEX(T)s demonstrate HARC.

Cass (11) reported that manifest DEXTs showed nonsuppression of the fovea and altered egocentric localization in which objects were projected as if the subject's eyes were straight during deviation, i.e., HARC.

Campos & Ciesi (12) observed HARC with no suppression for small angle XTs, while those subjects with larger angles showed suppression at the diplopia point of the deviating eye. This suppression sometimes exceeded the nasal field of the deviated eye and affected both eyes.

Cooper & Feldman (13) used a translucent hemisphere (perimeter) to present visual stimuli while monitoring eye position during binocular alignment and deviation. Their X(T)s did not suppress during alignment. They had HARC during deviation with an associated extension of the binocular field equal to the objective angle, which they called 'panoramic viewing'. The visual acuity of the deviating eye's fovea was still 20/20. They reported that neither the fovea of the deviating or fixating eye suppressed even though they had different egocentric localization.

Cooper & Dibble (16) used dissimilar, luminous, red-green targets presented on a dark, non-fusible background in an attempt to determine the depth of the suppression scotomas in the temporal retina. They found nonsuppression of the temporal retina even with the smallest stimuli and HARC. Black backgrounds eliminated suppression, while white backgrounds, such as used by Pratt-Johnson & Wee (3), resulted in active inhibition or suppression. Awaya et al (4) had found that foveal suppression was observed during both conditions of fusible and non-fusible backgrounds, but suppression of the diplopia point was only reported with non-fusible backgrounds.

The degree of artificiality or naturalness of the testing conditions may affect retinal correspondence. The Bagolini Striated Glasses Test elicits the highest percentage of ARC responses while the Hering-Bielschowsky afterimage test elicits the least for esotropia (17). This finding, however, is contrary to the data for intermittent exotropia (7,13,16). In these latter studies, X(T)s had more responses of NRC on the Bagolini striated glasses test than the Hering-Bielschowsky afterimage test.

Flom & Kerr (18) stated that ARC responses were not dependent on the test used. They said that the variability of responses was due rather to the lack of control of accommodation and eye position and alignment.

It is readily apparent that the aforementioned studies report various and not consistent sensory responses in X(T). It has been suggested that the stimuli, background, and/or eye position influences responses.

This present study investigated the effects of varying target stimuli and background parameters and assessed their influence on sensory responses during latent and manifest exotropia while controlling and monitoring carefully the eye position and binocular alignment and misalignment.

SUBJECTS AND METHODS

Subjects

Eight X(T)s of the DE or basic type between the ages of 9 and 61 years were randomly selected from among those patients being seen at the Optometric Center of New York, the clinical facility of the State College of Optometry. All had stereopsis on a random dot stereogram indicating bifoveal fixation. Five were female and three were male. Any subject exhibiting amblyopia, ocular pathology, or a chronic systemic disease was excluded from the study. None of the subjects had received previous orthoptic or surgical treatment for their X(T)s. All subjects signed consent forms as approved by the local IRB and agreed to have an extensive laboratory testing performed.

Preliminary Visual Tests

The following preliminary tests were performed: Snellen visual acuity and unilateral cover test with prism neutralization at 6 m and 40 cm; Randot and Titmus stereo tests; objective and subjective angle measurements with first degree fusion targets on the synoptophore; near point of convergence; and binocular versions. In addition, the following tests for retinal correspondence were performed in both the binocularly aligned and deviated positions: Brock String; Bagolini Striated Glasses; Hering-Bielschowsky afterimage test; red lens diplopia awareness; cheiroscope; Worth 4-Dot; and, physiological diplopia testing.

[Brock String Test: A string with three balls is extended from the nose of the patient to a wall. If the patient looks at the middle ball and has normal single binocular vision he/she will see two strings emanating from the eyes and crossing at the ball fixated upon. In addition, the nonfixated balls in front of and behind the center ball will be doubled or diplopic. Loss of one or part of one of the strings is indicative of suppression. Crossing of the strings at the fixated ball while an eye is deviated is indicative of HARC.]

Experimental Procedures

All stimuli were presented using the Computer Orthoptics Vergence II liquid crystal system™ (RC Instruments, Cicero, Indiana) electronic haploscopic device. The subjects were fully corrected optically with glasses or contact lenses while viewing the computer-generated visual stimuli displayed on a 65 cm color computer display terminal (CRT). The right and left eye images on the CRT were alternately displayed, oscillating at 60 Hz. and matched to the liquid crystal display (LCD) glasses worn by the subjects. Cross-talk and ghosting were not evident.

The subject sat directly in front of the CRT at a viewing distance of 120 cm. The CRT screen subtended a viewing angle of 20 degrees to the subject. Eye movements and position and alignment were continuously monitored using an infrared eye movement system (Gulf and Western, Eye Trac Model 200). This system has a bandwidth from DC to 250 Hz, a resolution of 0.2 deg, and a linear range of ±10 degrees. The infrared sensing devices were mounted onto the LCD glasses. The sensors were adjusted according to the subject's pupillary distance. Both eyes were simultaneously monitored by the system during all phases of testing. Eye movements were recorded on-line using a two channel strip chart recorder. Extraneous head movements were reduced with a headrest device.

For each stimulus presented, the screen luminance varied as follows:
stimulus 1- 12.10 ±3.87 candela/m2;
stimulus 2- 31.50 ±12.46 candela/m2;
stimulus 3- 36.32 ±11.6 candela/m2;
stimulus 4- 19.06 ±1.54 candela/m2.

Calibration was performed prior to testing in a dark room. Subjects made responses to the stimuli using hand signals (thumb up for 'yes'; thumb down for 'no'). Testing was performed while the subject's eyes were binocularly aligned as well as when deviated. Their X(T) deviation was induced by momentarily occluding the habitually deviating eye. If there was no eye preference during pretesting, one eye was randomly selected as the 'non-preferred' eye and was occluded until it drifted out. The 'preferred' eye always maintained fixation throughout the testing. The subject's eye position and binocular alignment was constantly monitored throughout the experiment.

Stimulus 1 - Complex Stereoscopic Target with Temporal Suppression Stimuli

The subject was shown a large-field binocularly viewed stereoscopic multicolored picture as seen in a non stereoscopic black and white version in Figure 1, ->. Superimposed on the left half were five white letters which were seen only by the right eye. Superimposed on the right half were five white numbers which were seen by the left eye only. Fixing the central "X", the letters and numbers were therefore projected on the temporal retina of each eye. The optotypes were separated by a viewing angle of 51 min. of arc and subtended 210 min. of arc. The subject was instructed to look at the central "X" and report the appearance of the optotypes. Measurements of suppression zones were performed during both the binocularly aligned and deviated conditions.

Stimulus 2 - Complex Target Presented only to the Deviating Eye

The background picture was presented only to the deviating eye while the fixating eye viewed a white cross (view angle 174 min. of arc) with a surrounding white circle (view angle 780 min. of arc) on the same side of the screen as the fixating eye. (Figure 2 ->) The monitor was moved laterally until the cross was directly in front of the fixating eye. Fixating the cross, the subject was then questioned about what he/she saw, i.e., ? the cross, the circle, the background, complete?, position?

Stimulus 3 - Complex Target in Front of Fixating Eye and Perimetric Target in Front of Deviating Eye

The same full field scene but now presented in front of the fixating eye with a white cross superimposed (view angle 174 min. of arc) seen in Figure 3->. The deviating eye only viewed a white dot (arrow) which was moved by the examiner as in perimetry. The examiner began perimetry at both the diplopia point and fixation point. Measurements were performed with nine white dots of decreasing size (beginning with a dot of view angle 152 min. of arc), or until the subject could not resolve the dot. Measurements were preformed in both the aligned and deviated positions. Suppression and location were recorded.

Figures 1-3 (Cooper et al): Stimuli 1-3; See text to the left for details

TABLE 1

PRELIMINARY CLINICAL TEST RESULTS DURING OCULAR DEVIATION

S #	DCT	NCT	BS	BAG	AI	SYN	RL	CHR	W4	P DIPL	RDS
1	40	40	ARC	NRC	SUP	—	NRC	SUP	NRC	SUP	+
2	20	02	NRC	NRC	ARC	—	—	SUP	—	SUP	+
3	40	35	NRC	NRC	NRC	NRC	NRC	ISUP	ARC	SUP	+
4	25	10	NRC	NRC	ASUP	NRC	NRC	—	NRC	DIPL	+
5	35	35	SUP	SUP	ARC	NRC	ASUP	—	ASUP	SUP	+
6	27	30	HARC	HARC	ARC	ARC	ARC	NRC	NRC	DIPL	+
7	14	12	NRC	NRC	NRC	NRC	NRC	NRC	NRC	SUP	+
8	18	18	SUP	ARC	ARC	NRC	—	—	NRC	SUP	+

KEY: S# = SUBJECT NUMBER

TESTS:

DCT = DISTANCE (6m) COVER TEST, in prism Diopters — RL= RED LENS TEST

NCT= NEAR (40 cm) COVER TEST, in prism Diopters — CHR = CHEIROSCOPE

P DIPL = PHYSIOLOGICAL DIPLOPIA — W4 = WORTH 4 DOT

BAG = BAGOLINI STRIATED GLASSES TEST — AI = AFTERIMAGE TEST

SYN = SYNOPTOPHORE TESTING — BS = BROCK STRING

RDS = RANDOM DOT STEREOGRAM

RESPONSES:

ARC = ANOMALOUS RETINAL CORRESPONDENCE — + = PASSED TEST

HARC = HARMONIOUS RETINAL CORRESPONDENCE — - = FAILED TEST

NRC = NORMAL RETINAL CORRESPONDENCE — SUP = SUPPRESSION

ISUP = INTERMITTENT SUPPRESSION

ASUP = INTERMITTENT ALTERNATE SUPPRESSION

Stimulus 4 - Simple Perimetric Target

Both eyes viewed a black background. The fixating eye viewed a white cross while the deviating eye viewed a white dot. The dot was moved by the examiner beginning at the diplopia point and fixation point. Suppression scotomas were plotted using nine dots of decreasing size (beginning with a dot of angular measurement 152 min of arc). Measurements were preformed in both the aligned and deviated positions.

RESULTS

The results of retinal correspondence testing performed during binocular alignment (orthotropia) demonstrated that all subjects had NRC during testing and demonstrated at least 40 sec of stereopsis on random dot stereograms.

Table 1, previous page, depicts various clinical tests of retinal correspondence. Traditional tests for ARC yielded variable results with no one consistent correspondence response noted for any single test. The highest number of ARC responses were, however, found with the afterimage test.

Table 2, below, presents the findings for each of the eight subjects during binocular deviation for each of the four test experimental conditions. It depicts the incidence of responses of different types of retinal correspondence, i.e., HARC, NRC, UHARC. Seven of the 8 subjects tested demonstrated the same, i.e., dominant, response in three of the four test stimuli (75%). Four subjects demonstrated HARC; three demonstrated NRC, and one UHARC as the dominant or most common retinal correspondence response.

TABLE 2

TEST STIMULUS RESULTS DURING OCULAR DEVIATION

S#	STIMULUS 1	STIMULUS 2	STIMULUS 3	STIMULUS 4	SUMMARY
1	NRC	HARC	HARC	HARC	3/4 HARC
2	HARC	NRC	HARC	HARC	3/4 HARC
3	HARC	NRC	NRC	NRC	3/4 NRC
4	NRCw/ISUP	ISUP (central) HARC (peripherally)	NRC	NRC	3/4 NRC
5	NRC w/ SUP	—	HARC w/ISUP	HARC	2/4 HARC
6	SUP	HARC	HARC	HARC	3/4 HARC
7	ISUP	ISUP	NRC w/SUP	NRC	2/4 NRC
8	—	UHARC	UHARC	UHARC	3/4 HARC

KEY: S# = SUBJECT NUMBER

SUP = SUPPRESSION

ISUP = INTERMITTENT SUPPRESSION

NRC = NORMAL RETINAL CORRESPONDENCE

ARC = ANOMALOUS RETINAL CORRESPONDENCE

HARC = HARMONIOUS RETINAL CORRESPONDENCE

— = NO RESPONSE RECORDED FOR THIS STIMULUS

Table 3 is a summary table depicting the type of correspondence response observed as a function of each of the four stimuli used during testing. As is evident, stimulus conditions elicited an array of correspondence type responses with no common or dominant response noted for any one stimulus condition. However, there appears to be a trend in which the number of subjects who reported suppression was greatest for Test Stimulus 1, followed by Test Stimulus 2 (one suppression reported). There was no suppression reported for Test Stimuli 3 or 4. On the other hand, Test Stimuli 3 and 4 had the highest number of ARC responses.

DISCUSSION OF RESULTS

This study investigated the effect of varying stimuli and background parameters on sensory responses during latent and manifest exotropia. Previous studies reported that differences in sensory responses were due to variability of stimuli used during testing and/or the lack of control of the binocular deviation (tropia).

However, in this study, we monitored eye position constantly while the subject viewed the various stimulus conditions.

No one type of correspondence response was consistently found for all the subjects tested. When subjects were compared to each other, each displayed a different pattern of correspondence under different stimulus conditions. Each subject exhibited a common, or dominant, type of retinal correspondence response, defined as observed in 75% of the trials. It is important to note that all subjects exhibited different correspondence pattern types approximately 25% of the time.

The complexity of the background did not seem to effect retinal correspondence. However, the presence or absence of a background seemed to be related to the presence or absence of suppression. Complex picture vs blank background were more often associated with suppression.

Our findings contradict Awaya's study, which found different suppression patterns dependent on the presence of a fusible background (4). The liquid crystal display, used in this study, has many similarities with the Aulhorn phase difference haploscope used by Awaya. He tested suppression using a luminous white cross and a one degree white dot, both with and without fusible backgrounds. Without the fusible picture, he reported suppression at the fovea. With a brightly colored, fusible background, suppressions at the fovea and the diplopia point were found. It is possible that the differences between our findings and that of Awaya et al may be related to control of the X(T). Binocular alignment and misalignment clearly alters both suppression and retinal correspondence. It was not uncommon to find during testing, alterations in the binocular alignment. When this happened we re-established normal binocular alignment before resuming testing.

Other authors have also manipulated background stimuli to determine their effect on correspondence and suppression pattern. These studies have yielded conflicting results. For instance, Cooper & Dibble (16) used dissimilar targets on a dark background

TABLE 3

DISTRIBUTION OF RESPONSE TYPES FOR EACH STIMULUS

Test Stimulus 1	Test Stimulus 2	Test Stimulus 3	Test Stimulus 4
3 NRC	2 NRC	3 NRC	3 NRC
2 HARC	3 HARC	4 HARC	4 HARC
0 UHARC	1 UHARC	1 UHARC	1 UHARC
2 SUP	1 SUP	0 SUP	0 SUP

KEY: NRC = Normal Retinal Correspondence

UHARC = Unharmonious Anomalous Retinal Correspondence

HARC = Harmonious Anomalous Retinal Correspondence

SUP = Suppression(s)

and found that the X(T) subjects exhibited ARC and no suppression. But Pratt-Johnson & Wee (3) used a white background and found suppression from fovea to diplopia point, with HARC in the non-suppressed areas. Melek (5) used a white background and found suppressions and NRC.

In the present study there was no apparent relationship between stimulus condition and retinal correspondence in X(T). The differences in our findings compared to those of others may be explained by both control of the binocular alignment and the systematic changing of visual stimuli with a consistent method of presentation.

Burian (7) suggested that ARC was a sensory adaptation to a motor misalignment. He stated that "it [ARC] is essentially a faulty judgment of visual direction in which there is an attempt of the organism to adopt the sensorial condition of the visual apparatus to the anomalous motor condition in an attempt at a restoration of the [sensory] binocular cooperation". ARC is a process of adaptation of normal sensory responses to an anomalous motoric action. Visual direction is determined by spatial values of retinal elements. These spatial values are not absolutely fixed and can be sensorially altered. Hence, once a motoric deviation is made, there is a gradual shift in visual direction of one eye relative to the other, so that while "in normal binocular vision a given cortical locus may be fed excitations from a more or less restricted region... in strabismus this (excitation) may be supplied by (other) retinal areas" (9). Burian postulates that this occurs via sensory mechanism which may depend on the thresholds at the synapses. Clearly, X(T)s do not have a gradual change in their binocular alignment. The change is instantaneous. In addition, the greatest number of ARC responses were found on the most "unnatural" test for ARC, afterimages, and least on the most "natural" test, Bagolini's Striated Glasses Test. These two findings mitigate against the Burian concept of ARC.

Morgan (20) maintained that retinal projection, i.e. ARC/NRC, is a direct result of motor position. His theory is based on Urist's observation (21) that during voluntary version movements, afterimages move with the eyes causing a change in egocentric localization while during voluntary vergence movement, the afterimages do not change egocentric localization. Morgan postulated that these differences were dependent on whether the ocular movement was voluntary or involuntary, conjugate or disjunctive, saccadic or smooth, since each has a different underlying extraocular muscle innervation pattern. If the pattern was not registered via neurological feedback, there would not be a change in egocentric localization of perceived objects and, thus, NRC would be observed. If the innervational pattern was registered by feedback, the deviating eye would have a shift in egocentric localization and HARC would be observed.

Our findings partially support Morgan's theory. The fact that retinal correspondence could change shows that the binocular visual sensory system is not stable. Neither NRC or ARC is hard-wired and though one might be more probable, both response types can be solicited with different experimental conditions.

Our subjects, who ranged in age from 9 to 61 years old, did not show any age related difference in responses on any sensory tests. This has clinical implications for the orthoptic and surgical treatment of either the divergence excess or basic X(T). The visual system is capable of changing correspondence patterns, regardless of age.

The exact stimulus parameters which will elicit a change in correspondence pattern has not been determined. We further confirmed that X(T)s respond differently than esotropes. Our findings may have clinical ramifications in treatment. Since the detailed picture background increased the reporting of suppression, while the presence of a blank background often eliminated suppression, orthoptic treatment of suppression or ARC should begin with simple stimuli placed on a darkened background. This would minimize suppression and allow for the disruption of ARC. One such simple technique,which has been previously described, is to use a red glass with a penlight in a darkened room. Later, more detailed, larger stimuli should be gradually introduced. This type of procedure usually results in eliminating suppression and altering anomalous corresponding (22).

CONCLUSIONS:

Complex backgrounds resulted in the largest number of suppressions, whereas blank backgrounds decreased the number of reported suppressions.

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