Original Article

"Small In, Large Out" and "Luster": vision therapy feedback in adults with normal binocular vision

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ABSTRACT

Background: Feedback is an important component of vision therapy, providing information about visual performance and helping reinforce appropriate binocular responses. However, the frequency of different perceptual responses to commonly used vision therapy feedback techniques has not been well characterized in adults with normal binocular vision. This study aimed to determine the frequency and distribution of responses to the Small In, Large Out (SILO) and Luster vision therapy feedback techniques in a population of adults with normal ocular and binocular vision.

Methods: This cross-sectional observational study included participants with normal ocular examinations and binocular vision. A comprehensive ophthalmic and binocular vision examination was performed, including assessment of refractive error, corrected distance visual acuity (CDVA), stereoacuity, amplitude of accommodation, ocular alignment, and negative and positive fusional vergences (NFV and PFV) at distance and near. SILO feedback responses were assessed using eccentric circles and free-space fusion cards, while Luster feedback was evaluated using variable tranaglyphs (Bernell Corp., USA). SILO responses were classified as SILO, Small Out, Large In (SOLI), other responses, or no response. Luster responses were categorized as Shimmer, Half-half, Blended, Red, or Green.

Results: The study included 195 participants with a mean (standard deviation [SD]) age of 23.7 (4.3) years, 80 (41.0%) females and 115 (59.0%) males. SILO response categories differed significantly from an equal distribution ($\chi^2(3) = 96.47$, $P < 0.001$). SOLI was the most frequently reported response (n = 106, 54.4%), followed by other responses (n = 44, 22.6%), SILO (n = 26, 13.3%), and no response (19, 9.7%). Luster response categories also differed significantly from an equal distribution ($\chi^2(4) = 73.18$, $P < 0.001$). Half-half, Shimmer, Blended, Red, and Green responses were reported by 70 (35.9%), 66 (33.8%), 25 (12.8%), 17 (8.7%), and 17 (8.7%) participants, respectively.

Conclusions: Responses to both SILO and Luster feedback techniques varied considerably in adults with normal ocular and binocular vision, with SOLI predominating in the SILO test and Half-half and Shimmer predominating in the Luster test. These findings characterize the distribution of perceptual responses to these commonly used vision therapy techniques and provide descriptive reference data for interpreting feedback responses in similar adult populations. Future studies should investigate the reproducibility of these response patterns across diverse populations and determine their clinical relevance to vision therapy outcomes.

KEYWORDS

vision therapy, binocular vision, depth perception, visual perception, stereopsis, SILO feedback, Luster feedback

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INTRODUCTION

Binocular vision abnormalities are one of the most common eye problems and are associated with asthenopia, ocular pain, occasional diplopia, temporary blurred vision, and floating text while reading [1]. People with extensive near activities are more likely to have signs and symptoms associated with these visual impairments [2, 3]. Functional defects in binocular vision affect quality of vision and quality of life, as accuracy of binocular vision is a vital socioeconomic issue in modern societies. Accordingly, addressing and correcting these defects is essential for improving vision-related quality of life and optimizing academic and occupational outcomes [4].

Various treatment options are available for the management of binocular vision abnormalities, including refractive error correction [5, 6], office-based vision therapy [7, 8], home-based vision therapy [9, 10], prism prescription [11], and addition lenses [12, 13]. Among the options mentioned earlier, vision therapy is an effective approach for treating accommodative disorders and non-strabismic binocular vision anomalies [3, 8, 14–16]. Vision therapy, also known as vision training or orthoptics, is a term used to describe sensorimotor perceptual stimuli that improve visual skills such as eye movement and coordination [3].

Several principles can contribute to successful vision therapy. One important consideration is the incorporation of feedback into therapeutic exercises. Feedback can provide the optometrist with information about the patient's performance and progress during therapy, facilitating monitoring and treatment adjustments. It can also help patients become more aware of their visual performance and reinforce appropriate responses, thereby supporting motor learning and the acquisition of more effective visual behaviors [3, 17].

Two of the most commonly used feedback techniques are "Small in, Large out" (SILO) and "Luster" [18, 19]. In the SILO effect, while fusing a stereoscopic target and performing a chiastopic vision therapy task the fused virtual target will appear smaller than its real size and closer than its actual location as the patient increasingly converges. Doing the divergence task, the fused target will appear larger and farther than it is; the more divergence, the farther and larger the target will appear [18]. Another possible and common response to this technique is the small-out, large-in (SOLI) effect, where the fused target will appear smaller and farther during convergence and larger and closer during divergence [18]. These two responses are considered expected, though there could also be other, unexpected responses.

Luster is another feedback used in anaglyph exercises, reporting the color of the final fused target. Using red/green targets, possible responses will be Half-half (half of the fused target will be red, the other half green), Shimmer, Blended (mixture of red and green), and single color (red or green) [19].

To the best of our knowledge, no previous study has quantified the proportions of different perceptual responses to SILO and Luster feedback in a normal adult population. Therefore, the present study aimed to determine the types and proportions of responses to SILO and Luster feedback in normal adults.

METHODS

This cross-sectional observational study was conducted among participants with normal ocular examinations and binocular vision at Farabi Eye Hospital, Tehran, Iran. Recruitment and data collection took place between November 2022 and February 2024. The study was conducted in accordance with the tenets of the Declaration of Helsinki and was approved by the Ethics Committee of Tehran University of Medical Sciences. All participants received a verbal explanation of the study objectives and procedures, providing written informed consent before enrollment.

Individuals with a corrected distance visual acuity (CDVA) of 0.00 logarithm of the minimum angle of resolution (logMAR) or better, normal binocular vision, and normal ocular motility on examination were eligible for inclusion. Those with motor or intellectual disabilities, strabismus or decompensated heterophoria, accommodative or vergence anomalies, a history of amblyopia therapy, or previous ocular surgery were excluded. Participants who were unable to perform the study procedures or fuse the fusional cards were also excluded.

First, refractive error and CDVA were assessed. Refractive error was measured using an autorefractor (KR-800; Topcon Corporation, Tokyo, Japan), and the measurements were confirmed by retinoscopy using a Heine BETA 200 retinoscope (Heine Optotechnik, Herrsching, Germany). The spherical equivalent (SE) was calculated as the spherical power plus one-half of the cylindrical power. The spherical and cylindrical components of refraction and the calculated SE were recorded for each eye. CDVA was assessed at 6 m using an E-Snellen chart and recorded in logMAR notation.

Ocular alignment was assessed, and the angle of heterophoria was measured at distance (6 m) and near (0.3 m) using the alternate prism cover test with a 20/30 optotype [20, 21]. Ocular motility was evaluated using a standard motility examination, including assessment for extraocular muscle overshoot or undershoot [20, 22]. Stereoacuity was measured at 40 cm using the Titmus stereotest (Stereo Optical Company, Inc., Chicago, IL, USA) under standard room illumination. Participants wore polarized glasses and their refractive correction during testing, and the stereoacuity threshold was recorded in seconds of arc [23].

Amplitude of accommodation was measured using the push-up method with the participant's refractive correction. A near target was moved slowly toward the participant until sustained blur was first reported. The distance at which blur occurred was recorded, and the amplitude of accommodation was expressed in diopters (D), calculated as the reciprocal of the target distance in meters [24].

Negative and positive fusional vergences (NFV and PFV) were measured using base-in (BI) and base-out (BO) prism bars, respectively, held in the frontal plane [25, 26]. During horizontal fusional vergence testing, participants were instructed to maintain the fixation target as single and clear [25, 26]. Blur, break, and recovery points were recorded when participants first reported sustained blur, experienced diplopia, and regained single binocular vision, respectively [25, 26]. Following the break point, prism power was gradually reduced until single binocular vision was restored, and the corresponding prism value was recorded as the recovery point [25, 26]. These endpoints represent the onset of reported blur during vergence demand, the limit of maintained binocular single vision, and the ability to regain single binocular vision following the break [25, 26]. Although all three endpoints were measured, only break-point values are presented in Table 1. Prism bars were placed in front of the right eye for all measurements.

Anterior and posterior segment health was assessed using slit-lamp biomicroscopy (Haag-Streit, Koniz, Switzerland), with an auxiliary lens used for posterior segment examination [27]. Participants who met all inclusion criteria proceeded to the main visual feedback testing.

SILO effect: Eccentric Circles and Free Space Fusion Cards (Bernell Corporation, Mishawaka, IN, USA) were used to assess SILO feedback [18, 28]. These free-space orthoptic (also termed chiastopic) techniques were performed without spectacles, lenses, or prisms. Participants were instructed to fuse the two circles by diverging their visual axes beyond the plane of the cards (divergence task) or converging them in front of the card plane (convergence task). The resulting third, fused virtual circle was used as the perceptual endpoint. During a preliminary training session, participants became familiarized with the cards and were instructed in the fusion procedure. If participants were unable to achieve fusion voluntarily, a pointer was used to facilitate the task. For convergence, participants were instructed to fixate on a pointer held in front of the cards and move it back and forth until the fused stereoscopic image appeared; for divergence, they were instructed to fixate on a pointer or target positioned beyond the cards. The cards incorporated anti-suppression cues and accommodation controls. The SILO phenomenon is characterized by the perception of a fused target as smaller and nearer during convergence and larger and farther away during divergence [18]. Each card also incorporated anti-suppression cues and accommodation controls. Based on their responses to the Eccentric Circles, participants were classified into four groups: (1) SILO, (2) SOLI, (3) other responses, and (4) no perceptual response.

Luster effect: Bernell variable tranaglyphs (Series 500 and 600; Bernell Corporation, USA) were used to assess luster feedback [19, 28]. Binocular luster is a visual phenomenon elicited by dichoptic stimuli presenting differences in color or luminance contrast to the two eyes, resulting in a lustrous percept when the stimuli are fused [29, 30]. In the present study, participants were asked to fuse red and green targets and report their perceived color combination. Based on their responses, participants were classified into five mutually exclusive categories: Blended (a mixture of red and green), Shimmer, Half-half (half red and half green), Red, and Green.

Statistical analyses were performed using SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). The normality of continuous variables was assessed using the Shapiro-Wilk test. Continuous variables are presented as mean (standard deviation [SD]) with ranges reported as minimum and maximum values, categorical variables are expressed as frequencies and percentages. Separate one-sample chi-square goodness-of-fit tests were performed to compare the observed SILO and Luster response distributions with equal expected frequencies across their respective categories. Under the null hypothesis, each of the four SILO response categories had an expected proportion of 25% (48.75 participants per category), while each of the five Luster response categories had an expected proportion of 20% (39 participants per category). A P-value < 0.05 was considered statistically significant.

RESULTS

A total of 200 participants were initially recruited. Two participants were excluded because of a history of amblyopia therapy, another two because they were unable to fuse the shapes. One participant withdrew before completing the study procedures. Hence 195 participants were included in the final analysis. Participants' mean (SD) age was 23.7 (4.3) years; 115 (59.0%) were male and 80 (41.0%) female. All participants had a CDVA of 0.00 logMAR.

Mean (SD) SE of refractive error was −0.82 (1.61) D in the right eye and −0.83 (1.62) D in the left eye. Mean (SD) angle of heterophoria was −2.5 (2.2) prism diopters (PD) at near and −0.8 (1.2) PD at distance. Detailed descriptive statistics for age, refractive error, horizontal angle of heterophoria, fusional vergence ranges, stereoacuity, and amplitude of accommodation are presented in Table 1.

The distribution of SILO feedback response categories differed significantly from an equal distribution ($\chi^2(3) = 96.47$, $P < 0.001$). SOLI was the most frequently reported response, observed in 106 participants (54.4%), followed by other responses in 44 (22.6%), SILO responses in 26 (13.3%), and no response in 19 participants (9.7%).

The distribution of Luster feedback response categories also differed significantly from an equal distribution ($\chi^2(4) = 73.18$, $P < 0.001$). Half-half and Shimmer were the most frequently reported responses, occurring in 70 (35.9%) and 66 (33.8%) participants, respectively. Blended responses were reported by 25 participants (12.8%), while Red and Green responses were equally frequent, each occurring in 17 participants (8.7%).

Table 1. Descriptive statistics of participants' age, refractive error, heterophoria, fusional vergence, stereoacuity, and amplitude of accommodation

Variable			Mean ± SD (Range)
Age (y)			23.7 ± 4.3
Sex (Male/ Female), n (%)			115 (59.0) / 80 (41.0)
Refraction (D)	Right eye	Sphere	−0.68 ± 1.54 (−6.00 to 1.50)
		Cylinder	−0.27 ± 0.55 (−3.00 to 0.00)
		SE	−0.82 ± 1.61 (−7.00 to 1.13)
	Left eye	Sphere	−0.69 ± 1.55 (−6.00 to 1.50)
		Cylinder	−0.29 ± 0.58 (−3.00 to 0.00)
		SE	−0.83 ± 1.62 (−7.00 to 1.25)
Angle of heterophoria (primary position, PD)	Near	Horizontal	−2.5 ± 2.2 (−6.0 to 0.0)
	Far	Horizontal	−0.8 ± 1.2 (−3.0 to 0.0)
Fusional vergence break point (PD)	Near	Negative fusional vergence (BI)	19.0 ± 3.4 (9.0 to 35.0)
		Positive fusional vergence (BO)	27.9 ± 6.8 (16.0 to 40.0)
	Far	Negative fusional vergence (BI)	8.2 ± 2.7 (4.0 to 18.0)
		Positive fusional vergence (BO)	19.7 ± 7.5 (12.0 to 40.0)
Stereoacuity (seconds of arc)			40.0 ± 0.0 (40 to 40)
Amplitude of accommodation (D)			11.2 ± 2.2 (7.0 to 16.0)

Abbreviations: SD, standard deviation; y, years; D, diopter; Sphere, spherical component of refraction; Cylinder, cylindrical component of refraction; SE, spherical equivalent; PD, prism diopter; BI, base-in; BO, base-out. Note: SE was calculated as sphere plus half the cylinder.

DISCUSSION

This study characterized the distribution of perceptual responses to SILO and Luster feedback in adults with normal ocular and binocular vision. The principal finding was that the expected SILO response was reported less frequently than the SOLI response—specifically, 54.4% of participants reported SOLI and only 13.3% reported SILO; 22.6% reported responses that could not be classified as either SILO or SOLI, and 9.7% reported no perceptible change in target size or distance. Half-half and Shimmer were the most frequently reported responses for Luster feedback, accounting for 35.9% and 33.8% of participants, respectively. Blended, Red, and Green responses were less frequent. Both the SILO and Luster response distributions differed significantly from an equal distribution across their respective categories. These findings demonstrate considerable interindividual variation in the perceptual responses elicited by these two commonly used vision therapy feedback techniques, even among adults with normal binocular vision. However, the observed statistical differences from an equal distribution should be interpreted as descriptive findings and do not, by themselves, establish the clinical significance or therapeutic superiority of any particular response.

Perceptual feedback is an integral component of vision therapy, in which sensory cues, including retinal blur and disparity, provide information related to accommodative and vergence responses during training [3]. The SILO and Luster phenomena represent distinct perceptual responses that may be elicited during vergence-related vision therapy tasks [18, 19]. However, to our knowledge, the frequency distribution of these responses has not previously been quantified in adults with normal binocular vision.

SILO feedback is commonly used during vergence training to provide perceptual information about the apparent size and spatial location of a fused stereoscopic target. Under the conventional SILO pattern, increasing convergence is associated with the perception of a smaller and nearer target, whereas increasing divergence is associated with the perception of a larger and more distant target [18, 31]. These perceptual changes may be partly related to oculomotor adjustments and mechanisms of size constancy [32]. Although SILO is conventionally described as the expected perceptual response, the present study found that it was less frequently reported than the SOLI response. Specifically, 54.4% of participants reported SOLI, whereas only 13.3% reported SILO. This observation adds to previous recognition of SOLI as an alternative perceptual response [16, 18]. Argiles et al. [18] described the use of vectograms to elicit the SILO effect during vision therapy and acknowledged that perceptual responses may vary between individuals. The present findings further indicate that the conventional SILO pattern should not be assumed to represent the perceptual response of every adult with normal binocular vision.

Several perceptual mechanisms may contribute to the occurrence of these different response patterns. One proposed explanation for the conventional SILO phenomenon involves size constancy, whereby the visual system compensates for changes in retinal image size associated with changes in viewing distance. Under natural viewing conditions, convergence and accommodation provide information about target distance. When an object approaches, its retinal image generally increases in size; nevertheless, the visual system uses distance-related information to maintain a relatively stable perception of its physical size. Conversely, when an object moves farther away its retinal image decreases in size while perceptual compensation helps preserve its apparent size [31, 32]. During a vergence exercise, the fused target may be perceived as changing in both size and distance, despite the absence of corresponding physical movement of the target. The interaction between retinal image size, vergence, and accommodation may therefore contribute to the characteristic SILO response [18]. Accordingly, during convergence the compensatory mechanisms involved in size constancy may contribute to the perception

of the target as smaller and closer despite its constant physical size, while during divergence these mechanisms may contribute to the perception of the target as larger and farther away.

Argiles and colleagues investigated the contribution of vergence and accommodative cues to stereo localization during the SILO effect in adults with normal binocular vision and accommodation [18]. Using Quoits vectograms, they found that stereo localization accuracy varied with vergence demand and that the accommodative convergence over accommodation (AC/A) ratio was associated with stereo localization accuracy under a particular base-out condition. Their findings suggest that vergence and accommodation provide relevant, although not necessarily exclusive, cues for perceived spatial localization during SILO-related tasks. Importantly, their study assessed localization accuracy and the relationship between visual cues and perceived target distance, rather than the population frequency of different subjective response categories [18]. The present study therefore complements their work by documenting the distribution of reported perceptual responses in a larger adult sample, while the mechanisms underlying those responses remain to be established.

The SOLI response may reflect a different weighting of the visual information available during a vergence task [18]. The predominance of SOLI over SILO in the present study may reflect individual differences in the weighting of retinal image size and oculomotor cues during vergence-related tasks. One possible explanation is that perceived changes in target size may be interpreted in relation to familiar size-distance associations; however, this proposed explanation remains speculative, as the underlying perceptual mechanisms were not directly investigated in the present study. As discussed by Argiles et al. [18], observers who report SOLI may rely more heavily on changes in retinal image size and less on vergence- and accommodation-related distance cues: during convergence the fused target may appear smaller, a reduction in apparent size that may be interpreted as indicating that the target is farther away, whereas during divergence the target may appear larger and thus be perceived as being closer [18]. This proposed explanation is consistent with the predominance of SOLI in the present adult sample. Nevertheless, the present study did not directly measure retinal image size, accommodative responses, AC/A ratios during the feedback tasks, or the relative weighting of monocular and binocular cues. Accordingly, this explanation should be regarded as a plausible perceptual interpretation rather than a mechanism established by our findings.

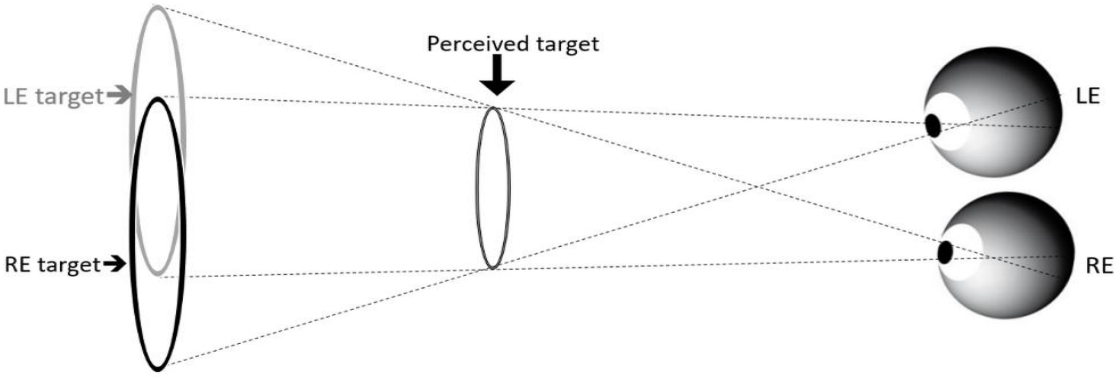


Figure 1. Original illustration created by the authors showing the geometric explanation of the Small In (SI) response in the SILO phenomenon. During convergence-induced fusion, the fused target may appear smaller and closer than the two real targets [18].

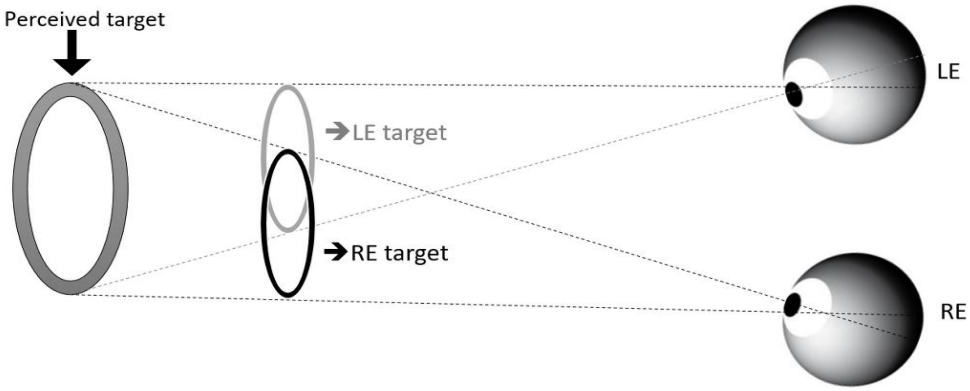


Figure 2. Original illustration created by the authors showing the geometric explanation of the Large Out (LO) response in the SILO phenomenon. During divergence-induced fusion, the fused target may appear larger and farther away than the two real targets [18].

The geometric illustrations in Figures 1 and 2 provide complementary visual explanations of how the relative positions of the monocular targets and their fused percept may contribute to the apparent size and distance changes associated with SILO [18]. Figure 1 illustrates the geometric explanation for the Small In response during convergence, Figure 2 illustrates the Large Out response during divergence. These diagrams help clarify the spatial relationships underlying the conventional SILO pattern. However, they should be interpreted as geometric illustrations rather than direct evidence that a single geometric or physiological mechanism accounts for all subjective responses. The occurrence of SOLI and other responses in the present study indicates that perceptual interpretation may vary even when the stimulus and binocular task are similar.

Scheiman and Wick described a clinical observation that children and younger patients may report SILO more commonly, whereas adults may be more likely to report SOLI [31]. The predominance of SOLI in our adult sample is consistent with this clinical observation. However, because the present study included adults only, it cannot establish an age-related difference or demonstrate that age or prior experience causes the observed response pattern. Developmental studies using other visual perceptual tasks have shown age-related differences in the relative influence of current sensory information and prior experience, although such findings have not been established for SILO or SOLI responses specifically [33, 34]. Direct comparisons between children, adolescents, and adults using the same stimuli and standardized response criteria would therefore be required to determine whether similar age-related differences occur in SILO and SOLI perception. An additional finding was that 22.6% of participants reported responses other than the conventional SILO and SOLI patterns. These responses are important because they suggest that the perceptual consequences of vergence-related feedback may not be adequately represented by a binary classification of SILO versus SOLI. The mechanisms underlying these alternative responses remain uncertain. Differences in the interpretation of apparent size and distance and the relative contribution of vergence and accommodation cues, attention, and individual response strategies may be relevant, but these possibilities were not directly evaluated in the present study. Similarly, 9.7% of participants reported no perceptible size or distance change despite having normal binocular vision and stereoacuity. This finding suggests that normal binocular function and measurable stereopsis do not necessarily guarantee that a participant will consciously perceive or report the expected feedback during a particular vision therapy task. This should not be interpreted as evidence of an underlying binocular dysfunction or deficient stereoscopic processing though. Further studies involving larger samples of individuals with normal binocular vision and patients with binocular vision disorders are warranted to characterize these alternative responses more comprehensively and elucidate the mechanisms underlying the unexpected findings of the present study.

Luster feedback is another commonly used technique in binocular vision training, particularly during anaglyph-based exercises. When dissimilar images are presented to the two eyes through red-green filters, the resulting binocular percept may be described as Half-half, Shimmer, Blended, or a single color corresponding to one of the monocular images [19]. In the present study, Half-half was the most frequent response (35.9%), followed closely by Shimmer (33.8%), then Blended (12.8%) and Red and Green (8.7% each). These findings indicate that the perceptual experience of Luster feedback varied considerably among adults with normal binocular vision, with no single response reported by a majority of participants.

Wendt and Faul [19] bring up how the binocular luster phenomenon has traditionally been described as a shimmering, lustrous, or glass-like appearance arising when the two eyes receive images that differ in luminance or contrast, while more recent psychophysical research suggests that binocular luster is associated with the interaction or conflict between incompatible monocular visual signals—particularly when the two eyes receive stimuli with different contrast polarities. Their review of binocular luster emphasizes that the phenomenon is related to broader mechanisms of binocular contrast processing and binocular rivalry, rather than attributable solely to the perception of surface properties. They also discuss evidence that chromatic differences between the eyes can elicit luster and that the response depends on the contrast relationships between the dichoptic stimuli [19]. These findings provide a perceptual and physiological context for interpreting the variety of responses observed during Luster feedback. The Half-half and Shimmer responses observed in the present study may reflect different subjective experiences of binocular combination under the conditions created by the red-green tranaglyphs. However, the distinction between these response categories was based on participants' reported perceptions and the study did not quantify intensity, duration, or temporal characteristics of the perceived effects. Consequently, the relatively high frequency of Half-half and Shimmer responses should be interpreted as a difference in the distribution of reported percepts rather than evidence that one response represents more effective binocular integration or better sensory fusion.

The single-color responses also warrant consideration. In the present study, equal proportions of participants reported Red and Green responses. Such responses may arise when the percept associated with one eye predominates over that associated with the other eye. Sensory eye dominance and binocular rivalry are potential contributors to this phenomenon [35, 36]. Strong sensory eye dominance may contribute to the perception of a single color corresponding to one eye's image, potentially reflecting an imbalance in interocular inhibition or binocular rivalry [35, 36]. However, a single-color percept during an anaglyph task does not by itself establish clinically significant sensory eye dominance, suppression, or binocular dysfunction, as sensory eye dominance may also be present in individuals with normal binocular vision and stereopsis [35, 36]. The relationship between reported color and ocular dominance may also depend on the spectral transmission of the filters, stimulus characteristics, and the relative contrast and luminance reaching each eye. As the present study did not include an independent quantitative assessment of sensory eye dominance or binocular suppression during the Luster task, these interpretations remain tentative.

An important consideration is that the Luster responses recorded in this study were obtained using a clinical vision therapy technique with variable tranaglyphs, rather than the calibrated dichoptic stimuli typically used in laboratory psychophysical experiments. Experimental studies of binocular luster have shown that its appearance can depend on the relationship between the monocular images and their backgrounds, the magnitude and polarity of interocular contrast differences, and the spatial configuration of the stimuli [19, 30, 37, 38]. Therefore, the response frequencies observed in our study should be understood in the context of the specific clinical testing conditions and should not be assumed to represent universal proportions of binocular luster percepts across different stimulus configurations. Further investigations using standardized stimuli and quantitative measures of perceptual strength could help determine whether the response categories identified in clinical tranaglyph exercises correspond to distinct psychophysical characteristics of binocular luster [29, 38].

The findings of this study may inform the interpretation of perceptual feedback during vision therapy. Because SOLI was reported more frequently than SILO in this adult sample, clinicians should avoid assuming that all individuals with normal binocular vision will experience the conventional SILO response during vergence exercises. Similarly, the variability in Luster responses suggests that no single perceptual response should be presumed to be the universal manifestation of successful sensory fusion. These findings highlight the value of eliciting and documenting patients' subjective perceptual experiences during feedback-based exercises. However, the present study was descriptive and did not assess treatment outcomes, changes in vergence function, or the predictive value of individual feedback responses. Accordingly, the findings do not establish whether any particular response is associated with greater therapeutic benefit or should guide clinical management.

A principal strength of this study was a sample of 195 adults who underwent comprehensive ophthalmic and binocular vision examinations before the feedback assessments. The standardized assessment procedures and the systematic classification of responses to two commonly used vision therapy techniques allowed the response distributions to be described within a clearly defined population. To our knowledge, this is the first study to quantify the frequencies of different SILO and Luster feedback responses in a normal adult population. Nevertheless, several limitations should be acknowledged. First, participants were adults with normal ocular and binocular vision recruited from a single clinical setting in Tehran, Iran; therefore, the findings may not be generalizable to children, older adults, other populations, or patients with binocular vision disorders. Second, the cross-sectional design and descriptive response assessment did not permit evaluation of the test-retest reproducibility or stability of the reported percepts. Third, the study did not directly measure the physiological or psychophysical mechanisms that may underlie the different response patterns, including accommodation during testing, sensory eye dominance, binocular suppression, or the relative weighting of vergence and retinal image size cues. Last, although the observed distributions differed significantly from equal expected frequencies, these statistical findings do not establish the clinical significance of the response categories or explain why individual participants reported particular percepts. Future studies should examine the reproducibility of SILO and Luster responses using repeated assessments, standardized stimulus presentation, and more detailed quantitative measures of perceived size, distance, color, and luster. Comparative studies involving children, adults, and patients with specific binocular vision anomalies, particularly convergence insufficiency, could clarify whether response distributions vary according to age or binocular vision status. Investigations incorporating objective measures of accommodation, vergence, sensory eye dominance, and binocular suppression may also help identify factors associated with SILO, SOLI, and alternative responses. Ultimately, prospective clinical studies are needed to determine whether baseline feedback response patterns or changes in these patterns are associated with vision therapy outcomes. Such research would help establish the clinical relevance of these perceptual responses and clarify their potential role in the assessment and monitoring of binocular vision therapy.

CONCLUSIONS

SOLI was the most frequently reported response during SILO feedback therapy in adults with normal binocular vision, whereas the conventional SILO response was less common. A considerable proportion of participants reported alternative responses or no perceptible change, highlighting the variability of subjective perceptual experiences during vergence-related feedback exercises. During Luster feedback, Half-half was the most frequently reported response, followed by Shimmer and Blended, then Red and Green at equal rates. These findings evidence that perceptual responses to SILO and Luster feedback vary considerably among adults with normal binocular vision and that no single response should be assumed to be universal. The clinical significance of these response patterns and their relationship with vision therapy outcomes remains to be established.

ETHICAL DECLARATIONS

Ethical approval: The study was conducted in accordance with the tenets of the Declaration of Helsinki and was approved by the Ethics Committee of Tehran University of Medical Sciences. All participants received a verbal explanation of the study objectives and procedures and provided written informed consent before enrollment.

Conflict of interests: None.

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