Minimal Angle Horizontal Strabismus Detectable by Lay Observers

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ABSTRACT: *Purpose.* Patients with socially significant strabismus may be at risk for certain psychosocial consequences. However, the magnitude at which strabismus becomes socially significant is ill defined. Suggested criteria for socially significant strabismus can be found in the literature, but they are rarely, if ever, referenced. The purpose of this study is to further define the magnitude at which strabismus becomes socially significant according to lay observers. *Methods.* Strabismus was simulated using photo manipulation and off-center fixation. Horizontal deviations were created in 3Δ steps up to 24Δ. One model was used for all photos. The photos were presented in random order to non-health care professionals (N = 58). Participants were instructed to view each picture and determine: "yes, this person has an eye turn" or "no, this person does not have an eye turn." A χ^2 test was used for analysis. *Results.* There was an increase in the likelihood of strabismus detection as the size of the angle increased for exotropia and esotropia. Overall, exotropia was easier to identify than esotropia. For esotropia, a dramatic increase in detectability occurred between 9Δ (47.41% detection; p = 0.001) and 12Δ (67.24% detection; p = 0.001), with 70% detection being achieved at 14.5Δ. A significant increase in detection of exotropia occurred between 6Δ (60.34% detection; p = 0.001) and 9Δ (77.59% detection; p = 0.001), with 70% detection achieved at 8Δ. *Conclusions.* Our results suggest that exotropia is easier for lay observers to detect than esotropia, with the critical magnitude (70% detection) being 14.5Δ for esotropia and 8Δ for exotropia. This refutes generally accepted beliefs that esotropia is easier to detect than exotropia. Additional studies are needed to look at the effect of ethnicity, sex, and age. Multiple models should be used to reduce the possible influence of distinct facial characteristics and increase the generalizability of the results. (Optom Vis Sci 2004;81:505–509)

Key Words: strabismus, exotropia, esotropia, socially significant, prism diopter

Eye contact is an important part of our day-to-day interactions. Researchers and psychologists have shown that gaze and eye contact are used to provide information, regulate personal interactions, and express intimacy.[1] Therefore, those with abnormal eye contact, such as that resulting from socially significant strabismus, may be at a disadvantage and subject to psychosocial sequelae.[2–10]

Patients with strabismus have reported that they have been wrongly accused of cheating, day dreaming, and not paying attention.[2] Some have also reported that their condition has interfered with employment opportunities.[2, 11] There is evidence that these psychosocial effects may be alleviated as a result of treatment. Adults who have undergone strabismus surgery have acknowledged an increase in their self-esteem, confidence, attractiveness, and interactions with the opposite sex.[9] Psychologists have noted that children with strabismus also have an increase in their self-esteem if they undergo treatment of their condition.[12]

Given the impact and importance of socially significant strabismus, it is surprising that the criteria remain inadequately defined. When reading the literature, it is common to see a casual and anecdotal statement that esotropia is easier to detect than exotropia.[13–16] If a rationale for this statement is given, it is that the nose tends to make an esotropic deviation more apparent. Some authors suggest specific numbers for social significance as 15Δ of esotropia and 20Δ of exotropia.[15] Interestingly, many clinicians and one previous study by Reinecke et al.[16] do not necessarily agree with this statement.

Although not universally accepted, most criteria for surgical success of strabismus hinge on a residual horizontal deviation (regardless of direction) of <10Δ.[1, 2, 17] Although this number is typically not referenced, it is presumably based on minimizing the social significance of the strabismus and creating a situation in which monofixation syndrome may develop with peripheral fusion.

It is clear that, with the exception of the aforementioned study by Reinecke et al.,[16] the actual numerical criteria for socially significant strabismus remains ill defined. For this reason, we decided to attempt to identify the magnitude at which strabismus becomes socially significant and further add to the preliminary work done in this area.

METHODS

Strabismic deviations were simulated using photo manipulation and off-center fixation. A white female model was photographed using a high-quality digital camera at a distance of 1 m. The model had normal ocular alignment, an interpupillary distance of 58 mm, and angle κ of 0.5 mm nasal in the right and left eyes. Photos were taken of the model looking at the center of the camera lens and points 3, 6, 9, 12, 15, 18, 21, and 24 cm to her right. All points were marked for the subject on a ruler perpendicular to her line of sight, so that they corresponded to deviations in Δ of eccentric gaze (Fig. 1). Photos were taken in rapid succession to avoid any movement of the model other than the eyes, which was essential for proper photo manipulation.

A computer program was used to combine the orthophoric photograph with one eye from each of the eccentric gaze photos. One of the eyes was removed from the orthophoric photograph and then the two images were merged and blended (Fig. 2). Images of left esotropia and right exotropia were created in 3-Δ steps to 24Δ. Each of these photos was then flipped to simulate 3Δ to 24Δ of right esotropia and left exotropia. All images were printed on high-quality photo paper with the model's head measuring 120 mm horizontally and 130 mm vertically. One picture of each deviation was used in the study along with four orthophoric images, for a total of 36 photographs. Study design was reviewed and approved by the Institutional Review Board of The New England College of Optometry.

The photographs were shown to 58 non-health care professionals. These individuals ranged from office assistants to executives from a variety of professional backgrounds. All were aged >21 years and did not have socially significant strabismus. Observers were not asked about their ocular history or whether they had any previous knowledge of strabismus.

After an explanation of the study, each participant was required to sign an informed consent form. All participants were given the same set of instructions that included a brief definition of strabismus and explanation of the task. For each print, participants were asked to answer: "yes, this person has an eye turn" or "no, this person does not have an eye turn." It was further explained that the participant only had to identify the presence or absence of an eye turn, not the direction of the deviation or eye involved. Photographs were held at arm length and could only be viewed once. There was no time limit given for viewing individual photos. Each photograph was hidden from view after the decision was made to prevent comparisons. The examiner manually shuffled photographs between observers to randomize the order in which they were viewed. Results were analyzed using the χ^2 test.

RESULTS

There was a clear trend to the subjects' responses, with more people overall responding "yes, this patient has an eye turn" as the magnitude of the simulated eye turn increased (Table 1). There was a steady linear increase in the percentage of subjects responding yes for esotropia >3Δ. For exotropia, although the same gen-

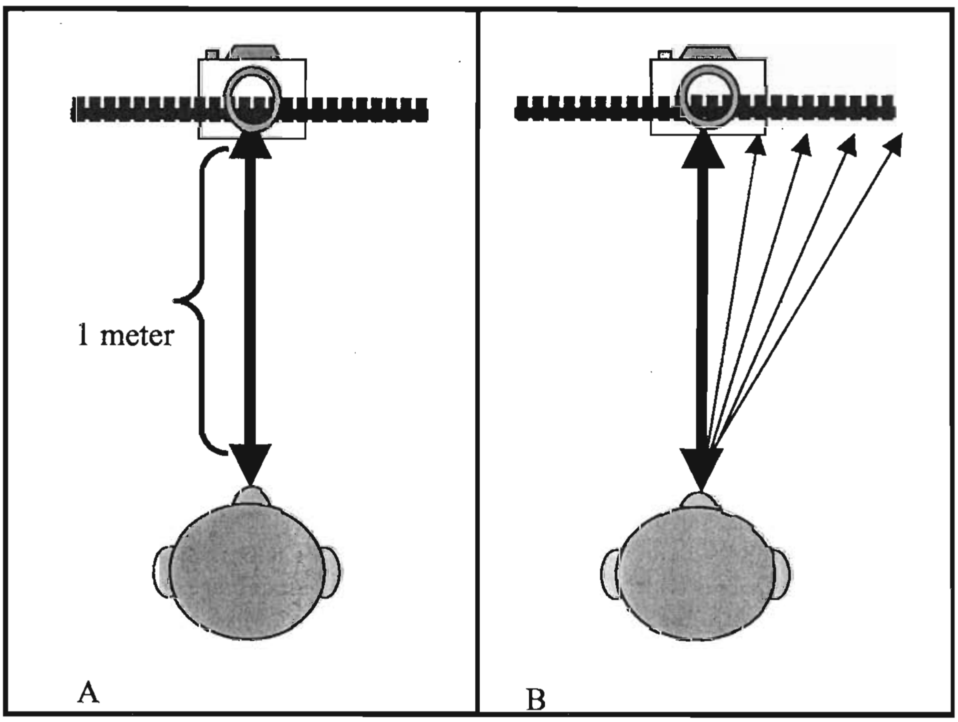

FIGURE 1.

Set up for eccentric gaze pictures used to simulate strabismus. A: Model positioned 1 m from camera and photographed looking at center of camera lens. B: Model photographed while looking off center to her right. A color version of this figure is available at www.optvissci.com.

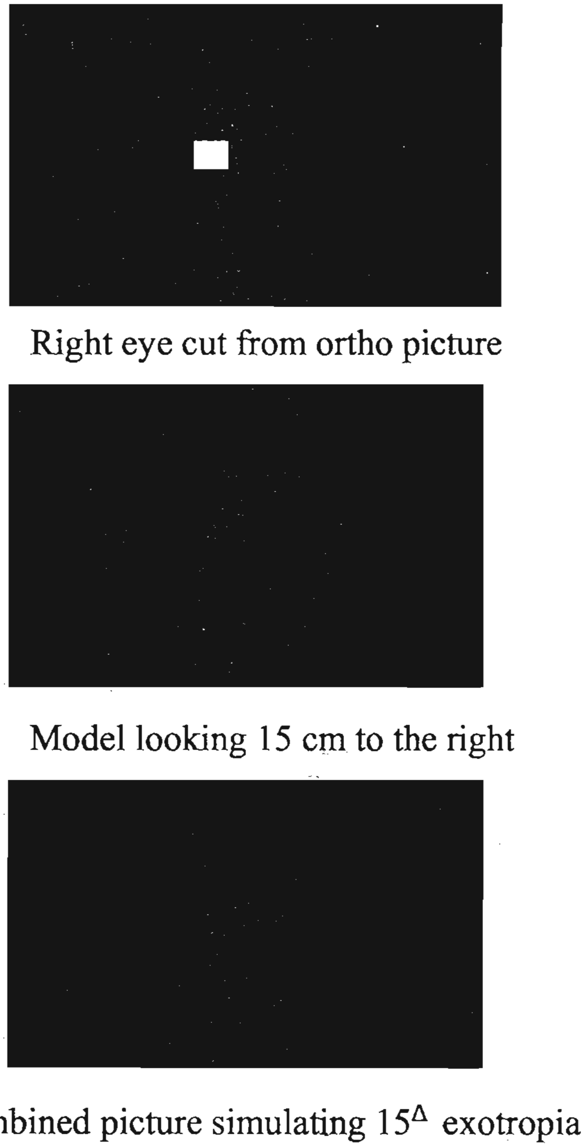

FIGURE 2.
Photo manipulation to simulate strabismus. Right eye removed from picture of model looking straight ahead and then combined with picture of model looking 15 cm to the right to create a simulated 15Δ exotropia. Color versions of this figure are available at www.optvissci.com.

eral trend exists, the responses fluctuated between 9Δ and 12Δ, 15Δ and 18Δ, and then again between 21Δ and 24Δ. However, these fluctuations all occurred after the percentage of subjects responding yes was >70% (critical threshold of detection) and were not statistically significant.

Overall, exotropia was more easily identified than esotropia until the magnitude of the eye turn exceeded 18Δ, at which point the percentage of subjects responding yes is >80% for both (see Table 1). For example, the percentage of yes responses at 6Δ of deviation was 36.20% esotropia vs. 60.34% exotropia; for 9Δ it was 47.41% esotropia vs. 77.59% exotropia; for 12Δ it was 67.24% esotropia vs. 72.41% exotropia; and for 15Δ it was 71.55% esotropia vs. 87.93% exotropia.

Somewhat surprisingly, the deviation that received the highest percentage of "no, this person does not have an eye turn" was not the ortho position but rather 3Δ esotropia (74.13%). However, this did not differ statistically when compared with the ortho position (68.97%; $p = 0.400$). For this reason, when using the χ^2 analysis, it did not matter whether the responses were compared with 3Δ esotropia or the ortho position (see Table 1 and Fig. 3).

Fig. 3 illustrates the percentage of "yes, this person has an eye turn" for increasing magnitudes of esotropia and exotropia. Fewer than 50% of the study population chose "yes, this person has an eye turn" for esotropia ≤9Δ and for exotropia ≤3Δ. For esotropia, a dramatic increase in detectability occurred between 9Δ (47.41% detection; $p = 0.001$) and 12Δ (67.24% detection; $p = 0.001$). A significant increase in detection of exotropia occurred between 6Δ (60.34%; $p = 0.001$) and 9Δ (77.59%; $p = 0.001$). The critical threshold for detection was chosen as >70% "yes, this person has an eye turn." This level was surpassed at 14.5Δ for esotropia and 8Δ for exotropia.

Of the 232 pictures of orthophoria shown, 72 were interpreted as strabismus, resulting in a 31.03% false-positive rate.

DISCUSSION

Results of our study suggest that exotropia becomes socially significant in small magnitudes and is easier for lay observers to detect than esotropia. Interpupillary distance and angle κ of our model fall into the normal range and therefore probably do not

TABLE 1.
Mean percent of subjects responding "yes, this patient has an eye turn," and chi-square results for 3–24Δ strabismus compared with the ortho position

Deviation (Δ)	Esotropia			Exotropia		
	"Yes, Patient has Eye Turn" (mean % of Responses)	Chi2	P value	"Yes, Patient has Eye Turn" (mean % of Responses)	Chi2	P value
0	31.03	—	—	31.03	—	—
3	25.87	2.09	0.4	45.69	12	0.005
6	36.20	9.34	0.01	60.34	48.01	0.001
9	47.41	15.54	0.001	77.59	125.3	0.001
12	67.24	71.69	0.001	72.41	98.6	0.001
15	71.55	90.94	0.001	87.93	176.9	0.001
18	83.62	149.9	0.001	82.76	146.4	0.001
21	96.55	232.8	0.001	98.28	245	0.001
24	97.41	238.8	0.001	95.55	232.8	0.001

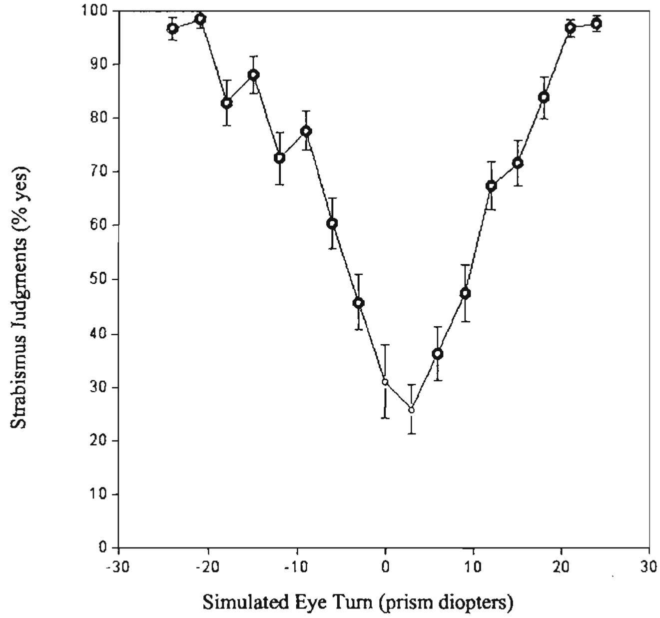

FIGURE 3.
Significant differences in the percent of "yes, this person has an eye turn" for esotropia and exotropia compared with either the ortho position or 3Δ esotropia. The negative and positive numbers along the x axis designate exotropia and esotropia, respectively. The percentage of subjects responding, "yes, this person has an eye turn" is represented along the y axis, and the black circles are statistically significant data points. A color version of this figure is available at www.optvissci.com.

contribute to the difference between detection of esotropia and exotropia in this study. Although this does not agree with generally accepted beliefs, our findings are similar to those of the only previously published study on this topic and are consistent with our clinical experience. Reineke et al.[16] found that the critical threshold of detection (>70% detection) for a group of observers was 7.5Δ of exotropia and 15Δ of esotropia. Using the same critical threshold of detection, our findings of 8Δ for exotropia and 14.5Δ esotropia are remarkably close. Given the similar results of the two studies, these results should have an impact in the research and clinical arenas.

Researchers should take these findings into account when designing future strabismus treatment studies that use socially significant strabismus as an outcome measure. Furthermore, care should be taken to use different outcome measures based on the direction of the resulting strabismus. Currently, most strabismus treatment studies on surgical success use a blanket criteria of 10Δ and do not distinguish between a resulting esotropia or exotropia.[1, 2, 17]

Clinicians should also be urged to take these results into consideration when counseling patients whose main motivation for treatment is the psychosocial consequence of strabismus. Furthermore, when the reduction of socially significant strabismus is the main motivation for treatment, surgeons may consider the importance of targeting a small angle esotropia as opposed to exotropia.

We would be remiss if we did not acknowledge several potential flaws in a study of this design. One major issue is that of generalizability. Certainly, specific facial characteristics of a patient are going to impact the appearance of strabismus. For example, we know that patients with wide nose bridges may be more likely to appear esotropic. It is difficult to account for such variations in a study of this nature without involving excessive number of models, and even then specific facial characteristics may not have truly been accounted for. The fact that this study and the one performed by Reneicke et al.[16] chose to use one white female model brings up the question of whether similar results would be achieved if a male model, model of a different age, or model of a different ethnicity were used.

Study participants were instructed to hold the photographs at arm length when making their decision. Because arm length is variable, the viewing distance was not consistent among the different observers. Furthermore, the pictures used during the study were photographed as if the patient was fixating at a distance of 1 m, but the angular subtense of the photographs was not consistent with this viewing distance. It is unclear what impact this mismatch of distances may have had on the results of our study.

Another area of concern is the potential impact of the directions given to the study participants. Certainly, the instructions chosen for this study, "does this person have an eye turn," may have biased the lay observer's judgments. The wording of our directions specifically told the participants to examine the pictures for the possibility of an eye turn. The focus on the potential existence of an eye turn likely made our participants more likely to suspect an eye turn than if the directions were more vague or general. This may partly explain our false-positive rate of 31.03%. An alternative directional set such as, "what, if anything, is wrong with this person's face" would have likely yielded different results.

Furthermore, the proportion of pictures depicting an eye turn in the study can affect a person's judgments. In the natural world, most people are not strabismic, and it is likely that an observer's tendency is to assume that people are not strabismic unless an eye turn is obvious. However, when subjects are asked to make this judgment among a series of pictures that mostly contain a person with a significant eye turn, they may be more likely to judge an eye to be turned. This effect may partly explain why there was a 31.03% response rate of "yes, this person has an eye turn" for the ortho pictures.

The results of our study may not accurately detect a lay observer's ability to detect strabismus in the real world because our participants were aware they were looking for strabismus. However, they may still be beneficial to predict satisfaction among patients who have undergone strabismus treatment and are concerned about cosmesis. This is because patients who have undergone strabismus treatment are often being "judged" by people who knew they had an eye turn and therefore are also looking for the strabismus as our participants were doing.

At this point, it is clear that additional research is needed if we are truly to pinpoint the amount of strabismus that is socially apparent to lay observers. For several reasons, it is likely that our study has resulted in strict guidelines; in the real world, the ability of lay observers to detect strabismus is not as good. Although the exact magnitude for socially apparent strabismus may be difficult to ascertain, the demonstrated difference between esotropia and exotropia is still valuable information that could have an impact on future research concerning strabismus treatment and clinical management of strabismus. We are currently working on additional research in this area to investigate the impact of ethnicity, age, and gender of the model, instructional set, and picture size on the threshold of detection.

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