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ABSTRACT

Objective To investigate the varying difficulty of Snellen letters in children with amblyopia.

Methods We tabulated the letter-by-letter responses of amblyopic and nonamblyopic fellow eyes on random, computer-generated Snellen lines. Participants were 60 children, aged 5 to 13 years, with a history of amblyopia. Main outcome measures were relative difficulties of Snellen letters and common misidentifications.

Results Errors were 7.5 times more common with certain letters (*B*, *C*, *F*, *S*) than with others (*A*, *L*, *Z*, *T*), this difference increasing to 17.6-fold at threshold. Similar relative letter difficulty was demonstrated at lines above and at visual acuity thresholds, and both difficult and easy letters were the same for amblyopic and nonamblyopic fellow eyes. Specific misidentification errors were often repeated and were often reciprocal (eg, *B* for *E* and *E* for *B*).

Conclusion Since therapeutic decisions in amblyopia management are often based on small differences in visual acuities, the relative difficulties of letters used in their measurement should be considered. The Early Treatment Diabetic Retinopathy Study system should be considered for use in this clinical setting.

Amblyopia represents the most common cause of decreased visual acuity in children and young adults.[1] Fortunately, its treatment is generally effective, especially in younger children. Since visual acuity is both the primary end point of treatment and the parameter most useful in making therapeutic decisions, its measurement is of critical importance in amblyopic children. Changes in visual acuity measured before and after treatment intervals and differences between fellow eyes may be ascribed clinical significance, even if measured differences are small.

Unfortunately, visual acuity measurement can be problematic for a variety of reasons.[2] Some are related to the nature of amblyopia: lines of optotypes are more difficult than single optotypes and letters are more difficult than figures.[3-4] Others are related to the nature of children: they may not remember the names of some letters and they may become confused or fatigued when presented an entire line of letters.

Although Snellen letters are often used to measure visual acuity in children who know the letters reliably, there are inherent difficulties in the Snellen chart itself. Some have been well described.[2,5-6] Children are adept at memorizing the letters, and there are fewer letters represented nearer the top of traditional wall or projected Snellen charts. Many of these difficulties have been addressed by the visual acuity charts originally developed for the Early Treatment Diabetic Retinopathy Study (ETDRS), and some of their features have been incorporated in commonly used, computer-based visual acuity systems.[7-8]

On the other hand, a common observation among clinicians experienced with visual acuity testing is that some letters are more difficult than others. Part of this problem may relate to the position of letters in a given line. The crowding phenomenon, typical in amblyopia, results in the common finding that single letters or letters at either end of a line may be more easily identified than those in the middle of the line. But our experience has been that some letters are particularly easy (eg, *L*, *T*, *A*) and some particularly difficult (eg, *B*, *S*, *C*) for both amblyopic and nonamblyopic fellow eyes, regardless of where in a line they are presented.

It has long been recognized that letters vary in difficulty.[9-12] Indeed, the Snellen chart excludes *I*, *J*, *M*, *Q*, *W*, *X*, and *Y* for this reason. The ETDRS charts are limited to only 10 Sloan letters (*S*, *K*, *H*, *N*, *O*, *C*, *D*, *V*, *R*, *Z*), which were initially considered to be of similar difficulty.[9] Even within this group, however, some letters were proved more difficult to identify than others (eg, *C* was 8.4 times as likely to be misidentified than *Z*).[10]

To our knowledge, the relative difficulty of the full range of Snellen letters has not been systematically investigated, children have not been the focus of previous studies, and the impact of amblyopia has not been described in this context. We were interested in addressing these issues and in defining any specific misidentifications that tended to recur.

METHODS

This prospective study was approved by the Albany Medical College institutional review board and was found to comply with the requirements of the US Health Insurance Portability and Accountability Act. Parental consents for tabulations of visual acuity measurements were executed prior to determination of best-corrected Snellen visual acuities of 60 consecutive children, ranging in age from 5 to 13 years. Children with other ophthalmologic conditions and those with developmental delays sufficient to preclude visual acuity measurements were excluded. An occluder or opaque tape was used for monocular testing.

All children had strabismic or anisometropic amblyopia, or a combination of the two, with visual acuities ranging from 20/20 to 20/100 (mean, 20/38.9; median, 20/40). Fellow eyes ranged from 20/20 to 20/100 (mean, 20/23.2; median, 20/25). Excluding 1 outlier, whose fellow eye was 20/100, the range was 20/20 to 20/40 in fellow eyes.

Lines of random Snellen letters, each 5 letters in length, were presented at distance using the M and S Technologies Smart System II PC-Plus (M and S Technologies, Skokie, Illinois). Best-corrected visual acuity end points were determined as the smallest line with fewer than half of the letters missed, assuming at least equivalent performance on larger lines. Data collected for each amblyopic and nonamblyopic fellow eye included which letters were presented, which were identified correctly and which were missed, and what specific errors were made in each presentation.

RESULTS

The number of presentations and the proportions correctly identified for each of the 19 letters used by the system are given in Table 1 for both amblyopic and nonamblyopic fellow eyes in order of increasing difficulty. As indicated in Table 2, amblyopic and nonamblyopic fellow eyes were statistically similar in their overall proportion of correct answers: the 95% confidence interval around the odds ratio of 0.83 included 1.0. The most difficult letters (Table 1) were *S*, *F*, *C*, and *B*. The easiest letters were *A*, *L*, *Z*, and *T*. For both amblyopic and nonamblyopic fellow eyes, the easiest and the most difficult quintiles were nearly identical and, as indicated in Table 3, the easiest 4 letters were identified correctly 7.5 times as frequently as the most difficult 4 letters.

Table 1. Percentages Correct Overall: Total, Amblyopic Eyes, and Nonamblyopic Fellow Eyes[a]

Letter	Correct No./Total No. (%)		
	Total	Amblyopic Eye	Fellow Eye
A	102/109 (93.6)	52/55 (94.5)	50/54 (92.6)
L	71/78 (91.0)	36/42 (85.7)	35/36 (97.2)
Z	96/106 (90.6)	45/49 (91.8)	51/57 (89.5)
T	99/111 (89.2)	46/54 (85.2)	53/57 (93.0)
E	96/123 (78.0)	46/61 (75.4)	50/62 (80.6)
U	48/63 (76.2)	21/29 (72.4)	27/34 (79.4)
P	79/108 (73.1)	41/55 (74.5)	38/53 (71.7)
H	66/91 (72.5)	38/57 (66.7)	28/34 (82.4)
D	87/120 (72.5)	52/70 (74.3)	35/50 (70.0)
V	56/78 (71.8)	28/42 (66.7)	28/36 (77.8)
O	70/98 (71.4)	29/44 (65.9)	41/54 (75.9)
N	49/69 (71.0)	35/47 (74.5)	14/22 (63.6)
R	69/99 (69.7)	32/49 (65.3)	37/50 (74.0)
K	43/63 (68.3)	21/33 (63.6)	22/30 (73.3)
G	57/89 (64.0)	30/47 (63.8)	27/42 (64.3)
B	42/66 (63.6)	22/36 (61.1)	20/30 (66.7)
C	73/118 (61.9)	37/58 (63.8)	36/60 (60.0)
F	58/101 (57.4)	37/62 (59.7)	21/39 (53.8)
S	4/22 (18.2)	2/11 (18.2)	2/11 (18.2)

[a] Letters are ordered in descending total percentage correct and divided into approximate quintiles. The mean (SD) percentage difference between amblyopic and nonamblyopic fellow eyes was 6.56 (4.24).

Table 2. Odds of Correct Reading in Amblyopic and Nonamblyopic Fellow Eyes

	No. of Readings		Total	Odds of Correct Readi
	Incorrect	Correct		
Amblyopic eyes	251	650	901	2.5896
Fellow eyes	196	615	811	3.1378
Total	**447**	**1265**	**1712**	

Abbreviation: CI, confidence interval.

Table 3. Odds of Correct Reading of Top-Quintile Letters (*A*, *L*, *Z*, *T*) and Bottom-Quintile Letters (

	No. of Readings			
	Incorrect	Correct	Total	Odds of Correct Readi
Top quintile	36	368	404	10.2222
Bottom quintile	130	177	307	1.3615
Total	**166**	**545**	**711**	

Abbreviation: CI, confidence interval.

A separate analysis of threshold data demonstrated relative letter difficulties similar to the full data set (Table 4). At threshold, however, the 4 easiest letters were identified correctly 17.6 times more frequently than the 4 most difficult (Table 5). The greatest separation between amblyopic and nonamblyopic fellow eyes was noted in *R*, *O*, *N*, and *K*. These letters were correctly identified 2.5 times more frequently at threshold by nonamblyopic fellow eyes than by amblyopic eyes (95% confidence interval, 1.1136-5.4334).

Table 4. Percentages Correct at Threshold: Total, Amblyopic Eyes, and Nonamblyopic Fellow Eyes[a]

	Correct No./ Total No (%)		
Letter	Total	Amblyopic	Fellow
L	29/30 (96.7)	14/15 (93.3)	15/15 (100.0)
T	39/41 (95.1)	16/17 (94.1)	23/24 (95.8)
Z	43/46 (93.5)	13/15 (86.7)	30/31 (96.8)
A	42/45 (93.3)	18/18 (100.0)	24/27 (88.9)
E	39/48 (81.3)	20/25 (80.0)	19/23 (82.6)
D	30/38 (78.9)	19/24 (79.2)	11/14 (78.6)
V	21/27 (77.8)	9/11 (81.8)	12/16 (75.0)
U	13/17 (76.5)	4/6 (66.7)	9/11 (81.8)
P	26/37 (70.3)	11/15 (73.3)	15/22 (68.2)
H	19/30 (63.3)	11/19 (57.9)	8/11 (72.7)
N	15/24 (62.5)	9/16 (56.3)	6/8 (75.0)
R	20/32 (62.5)	10/19 (52.6)	10/13 (76.9)
O	24/39 (61.5)	7/15 (46.7)	17/24 (70.8)
K	11/18 (61.1)	6/11 (54.5)	5/7 (71.4)
G	17/28 (60.7)	9/13 (69.2)	8/15 (53.3)
B	14/26 (53.8)	8/15 (53.3)	6/11 (54.5)
C	20/39 (51.3)	10/20 (50.0)	10/19 (52.6)
F	22/46 (47.8)	16/31 (51.6)	6/15 (40.0)
S	2/7 (28.6)	1/4 (25.0)	1/3 (33.3)

[a] Letters are ordered in descending total percentage correct and divided into approximate quintiles. The mean (SD) percentage difference between amblyopic and nonamblyopic fellow eyes at threshold was 10.45 (0.0747).

Table 5. Odds of Correct Reading of Top-Quintile Letters (*L*, *T*, *Z*, *A*) and Bottom-Quintile Letters (

	No. of Readings			
	Incorrect	Correct	Total	Odds of Correct Readi
Top quintile	9	153	162	17
Bottom quintile	60	58	118	0.9667
Total	**69**	**211**	**280**	

Abbreviation: CI, confidence interval.

Both amblyopic and nonamblyopic fellow eyes correctly identified letters at either end of each line 2.7 times as often as letters in the third position, or middle, of the line (Table 6). As seen in Table 7, no statistical difference was found between letters at the very beginning and very end of the line (the confidence interval of the odds ratio included 1.0).

Table 6. Odds of Correct Reading of Letters in Positions 1, 3, and 5 at Threshold[a]

	No. of Readings			
	Incorrect	Correct	Total	Odds of Correct Readi
Position 1 and 5	53	197	250	3.717
Position 3	53	72	125	1.3585
Total	**106**	**269**	**375**	

Abbreviation: CI, confidence interval.
[a] Lines were composed of 5 letters. No significant difference was found between positions 1 and 5.

Table 7. Odds of Correct Reading of Letters at the Beginning and End of a Threshold Line

	No. of Readings			
	Incorrect	Correct	Total	Odds of Correct Readi
Position 1	21	104	125	4.9524
Position 5	32	93	125	2.9063
Total	**53**	**197**	**250**	

Abbreviation: CI, confidence interval.

Interestingly, the specific errors were similar for both amblyopic and nonamblyopic fellow eyes. Several errors were reciprocal: *B* was misidentified as *E* in 58% and *E* as *B* in 70% of errors involving these letters. *F* was misidentified as *P* in 74% and *P* as *F* in 41%. *H* was misidentified as *N* in 76% and *N* as *H* in 55%. *U* was misidentified as *V* in 53% and *V* as *U* in 50%. *C* was misidentified as *O* in 75%, *D* as *O* in 70%, and *G* as *O* in 59%. *K* was misidentified as *R* in 45%, *P* as *R* in 41%, *R* as *A* in 67%, and *Z* as *Y* in 80%.

COMMENT

Our experience with random presentations of Snellen letters confirms the common impression, formerly reported, that some are more difficult than others.[9-13] Indeed, some letters are so difficult as to be excluded in both Snellen and ETDRS charts. The most difficult Snellen letters were *S*, *F*, *C*, and *B* ; the easiest were *A*, *L*, *T*, and *Z*. We were particularly interested to find that both amblyopic and nonamblyopic fellow eyes had difficulty with similar letters and that difficult letters were relatively difficult and easy letters relatively easy both at threshold and at lines above threshold.

Although some letters of moderate difficulty (*R*, *O*, *N*, *K*) seemed relatively better able to distinguish amblyopic from nonamblyopic fellow eyes, the strength of this difference was not compelling. Further, we do not have the capability to limit the letters presented to only these 4.

Although they have not been extensively studied, the specific errors we identified are familiar to those who regularly measure visual acuities.[14] Again, errors were similar for amblyopic and nonamblyopic fellow eyes: *B* and *E*, *F* and *P*, *H* and *N*, and *V* and *U* were common confusions. Several letters of similar contour were confused with *O*: *C*, *G*, and *D*.

We recognize limitations inherent in this small, single-center study using 1 computerized visual acuity system. The ETDRS studies, by contrast, included more patients but reported only the errors made on the threshold line.[10] Our data set included 1712 letter presentations in 120 eyes of 60 children. We found many of the same Snellen letters as the ETDRS letters to be among the most difficult, especially letters with contours, as opposed to straight lines. On the other hand, some differences may have resulted from the selection of the letters and the protocol used: the ETDRS chart used only 10 Sloan letters presented in 14 consistent sequences, while our Snellen-based system used 19 letters presented entirely at random.

As has been previously reported, the relative position of letters in a given line influences their difficulty: earlier letters are easier than those in the middle of the line, perhaps because the middle letters appear “crowded,” especially to the amblyopic eye.[15] Letters at the beginning of the line may be easier, not only because there is no crowding to the left but also because more effort may be expended before fatigue sets in toward the middle and end of the line.[10] Our data confirm that letters at the beginning and end of the line were easier than letters in the middle. But we found that letters at the end of the line were as easy as those at the beginning of the line, suggesting that crowding within a given line may have been a more important factor than fatigue, even for nonamblyopic fellow eyes.

In conclusion, our data indicate that both amblyopic and nonamblyopic fellow eyes have difficulty identifying the same letters and make similar specific errors, both at threshold and on larger lines, and that position within the line influences difficulty. Children with amblyopia appear similar in all regards to the adults previously reported. Some letters are as much as 7.5 times as difficult as others, this difference increasing to 17.6-fold at threshold. In determining appropriate levels of occlusion or penalization, clinicians should therefore consider the relative difficulty of letters used when deciding whether small sequential or interocular differences in visual acuity are significant. The easiest and most difficult letters might best be excluded. The ETDRS lines, although comprising letters of varying difficulty, have the advantage of balancing easy and difficult letters within each. We recommend that the ETDRS system be considered for use in amblyopic subjects.

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