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A comparison of the visual-verbal response time (automaticity) between first and fourth grade students using number, letter, and modified Landolt C stimuli

Dale H. Bricker  
*Pacific University*

Derek W. Gaume  
*Pacific University*

Gwendolyn J. Gilbert  
*Pacific University*

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A comparison of the visual-verbal response time (automaticity) between first and fourth grade students using number, letter, and modified Landolt C stimuli

Abstract
Several diagnostic tests in optometry categorize patient performance as pass or fail depending on how quickly and accurately he or she can verbalize targets. When testing children with such relative response time tests, a significant number fail for reasons other than visual factors. Visual-verbal automaticity, which is dependant on a patient’s cognitive-linguistic processing skills, is one such factor that affects performance. The purpose of this within subject design study was to investigate the effects of automaticity upon a relative response time test using familiar vs. unfamiliar targets. We measured the relative response times of eighty-nine fourth grade and one hundred and five first grade subjects in each of four test conditions. Results indicate: (1) Data obtained from adult relative response time test studies cannot be directly applied to school age children; (2) Relative response time tests without an age appropriate automaticity baseline should be considered suspect; and (3) Additional visual-verbal response time norms for various targets need to be established for every age group.

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A COMPARISON OF THE VISUAL-VERBAL RESPONSE TIMES
(AUTOMATICITY)
BETWEEN FIRST AND FOURTH GRADE STUDENTS
USING NUMBER, LETTER,
AND MODIFIED LANDOLT C STIMULI

By

DALE H. BRICKER
DEREK W. GAUME
GWENDOLYN J. GILBERT

A thesis submitted to the faculty of the
College of Optometry
Pacific University
Forest Grove, Oregon
for the degree of
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Advisor: Hannu R.V. Laukkanen, O.D.
Dale H. Bricker

Derek W. Gaume
Derek received his undergraduate degree in 1988 from the University of Calgary in Alberta, Canada and attended Pacific University College of Optometry from 1988-1992. He will receive his doctorate on May 17, 1992 and plans to return to Canada to enter private practice after graduation.

Gwendolyn J. Gilbert
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ABSTRACT

Several diagnostic tests in optometry categorize patient performance as pass or fail depending on how quickly and accurately he or she can verbalize targets. When testing children with such relative response time tests, a significant number fail for reasons other than visual factors. Visual-verbal automaticity, which is dependant on a patient's cognitive-linguistic processing skills, is one such factor that affects performance. The purpose of this within subject design study was to investigate the effects of automaticity upon a relative response time test using familiar vs. unfamiliar targets. We measured the relative response times of eighty-nine fourth grade and one hundred and five first grade subjects in each of four test conditions. Results indicate: (1) Data obtained from adult relative response time test studies cannot be directly applied to school age children; (2) Relative response time tests without an age appropriate automaticity baseline should be considered suspect; and (3) Additional visual-verbal response time norms for various targets need to be established for every age group.

Key Words: Accommodative facility, automaticity, Landolt C, lens rock, relative-response time tests, visual-verbal response time.
INTRODUCTION

Of the many optometric tests currently in use, there are several that assess specific visual performance parameters as a function of time. In most cases, these tests are dependant upon a verbal response by the subject. Because visual ability is not directly measured, but rather inferred from how long it takes the subject to verbally respond, these tests can be identified as relative response time tests (RRTT's). The Developmental Eye Movement Test (DEM)\(^1\) and the King-Devick (KD)\(^2\) are familiar examples of relative response time eye movement tests, whereas lens rock and prism rock are relative response time facility tests of accommodation and convergence.

With the exception of Richman's\(^3\) important work, little optometric research has been devoted to exploring how long it takes a subject to visually recognize and verbally identify targets. Put another way, it is currently undetermined as to what proportion of a relative response time test result is solely consumed by visual-verbal/cognitive factors. There are several other questions related to this area of research. How important is target selection in the validity of a relative response time test? Is visual-verbal/cognitive processing time a developmental function? And if so, at what age(s) is it a confounder in relative response time tests and at what age(s) does it plateau.

Previous investigators\(^3-9\) have recognized the importance of visual-verbal response time in such complex tasks as reading. This factor has been dubbed automaticity. When children first learn to read, the process is slow and laborious and may proceed on a letter by letter basis. After
considerable experience, reading becomes faster and words may activate their cognitive representations without involvement of the attentional center. After attaining that level of proficiency, many of the reading sub-processes have become "automatized" and can occur simultaneously with other tasks without interference. A series of studies by Samuels showed that skilled readers possess the ability to decode words automatically, thus requiring little attention. Poor readers on the other hand, use more attention to decode the stimuli. A study by Hall and Moon investigated the effects of familiarity (English vs. Non-English letters) on automaticity, and found that practice effects accounted for 42% of the variance in response times for an aural reading task.

If we rely upon previous research from the "learning to read" process as a model for exploring the potential role of automaticity in RRTT's, several inferences can be made. If an individual performing a RRTT has not previously automatized the target stimuli, considerable attentional/cognitive resources may be expended in simply identifying the target verbally. This could conceivably cause slow performance unrelated to visual performance variables. Also, automaticity may in part be a developmental function and poor readers may be more likely to fail RRTT's.

Argenbright and Beaudoin attempted to limit the developmental effect of automaticity on lens and prism rock performance by introducing unique modified Landolt C target stimuli that would be equally familiar (or unfamiliar) to both age groups (first and fourth graders) they targeted. Previous research indicates that an unfamiliar, or newly learned association such as the modified Landolt C, should not be processed
Argenbright and Beaudoin's results utilizing the modified Landolt C stimuli yielded significantly slower accommodative facility means than previously reported lens rock data using letters as target stimuli. This is very suggestive evidence that automaticity plays a significant role in RRTT performance.

The purpose of this study is to investigate the effect of automaticity on various targets (letters vs. numbers vs. modified Landolt C's) utilizing a relative response time test paradigm. Comparison between first and fourth grade subjects for all targets will also be made, as well as a comparison of any differences that may exist between schools. Finally, further normative data will be gathered for the +/- 2.00 diopter lens rock using the modified Landolt C target stimuli and will be compared with similar data gathered by Argenbright and Beaudoin, and Mackner and Onorato.

METHODS

Subjects:

A total of 194 elementary school children participated in this study: 105 first graders and 89 fourth graders. Subjects were recruited from five elementary schools within a 35 mile radius of Forest Grove, Oregon, a predominantly suburban, middle income socioeconomic area. All schools were regular participants in the Pacific University College of Optometry Vision Screening Program and data was collected only from students who had first passed the standard PUCO Vision Screening (see Appendix A).
Materials:

Three different test targets were used in order to evaluate the effect of target type on subjects' visual-verbal response time. The targets used were:

1. Numbers: Single digit numbers ranging from 0 to 9
2. Letters: Upper case Sloan letters
3. Modified Landolt C's: Targets introduced by Argenbright and Beaudoin

Modified Landolt C's are similar to standard Landolt C targets, except that the options of left (↺) and right (↻) opening targets were excluded in order to reduce subject laterality/directionality processing demands. These two options were replaced by two unique modifications of the Landolt C which are not dependent on the concepts of left and right. Therefore, the four Landolt C options used in our study were:

a. A single opening facing up ⊙
b. A single opening facing down ⊗
c. Two openings - one up and one down ↕
d. No openings (i.e. ring or circle) ⊚

All targets were produced with the aid of a Macintosh computer using Aldus Freehand 2.0 software for the numbers and letters and Full Paint 1.0 software for the modified Landolt C's. Targets were designed to create a 20/40 visual acuity demand at 40 cm and were presented in pairs on standard sized 4" x 5" near-point cards (See Appendix B). The two targets per card were centered and separated by 5.5 arc minutes, or 2.5 mm.
Two target symbols were printed on each card in order to conform to the previous test protocol of Argenbright and Beaudoin\textsuperscript{11}. The objectives of this type of target presentation were to: 1) reduce the odds of a subject correctly guessing the Landolt C target from one in four to one in sixteen; 2) prevent subjects from looking ahead during the lens rock; and 3) minimize the need for accurate eye movement ability by the subject.

Each pair of target symbols per card was randomly selected by the computer and printed on heavy bond white paper using an Apple LaserWriter. After printing, all cards were protected with clear reduced-glare plastic lamination.

**Procedures:**

Each testing station included an adjustable back support stool and a desk with a slanted surface of approximately 20 degrees and bottom lip to prevent material from sliding off. Each subject was seated comfortably at the testing station wearing his/her habitual near correction and the chair height was adjusted so that the viewing distance from the subject's eyes to the target plane was 40 cm. The examiner monitored and encouraged each subject to maintain the correct viewing distance throughout the testing. Once the subject was seated properly, illumination at the target plane was verified to be 100 foot candles with a GE Light Meter. The 100 foot candle illumination was achieved with an adjustable swing-arm lamp and 50 watt incandescent bulb supplementing the standard overhead room illumination.

The order in which the three test conditions were administered to each subject was randomized to eliminate any possible learning influence.
on the data. Prior to each of the three conditions, a demonstration was given to familiarize the subjects with the target used (see Appendix C). The demonstration of each target type was repeated as necessary to ensure the subject could identify the target symbols before continuing. The demonstration cards were constructed to resemble the actual test cards (with the exception that the demonstration target symbols were larger) in order to give subjects a good understanding of what they could expect during testing. For the demonstration cards, two 2.5 cm targets were drawn with a wide black felt-tip pen on white 4" x 5" cards, using the same numbers, letters, and modified Landolt C symbols as printed on the test cards. As might be expected, demonstration of the modified Landolt C targets required considerably more time than did the numbers or letters.

Following the demonstration of each target type, an instructional set was given to explain the response time testing procedure (see Appendix D). Testing and timing began when the examiner placed the first test card before the subject. Immediately after those two target symbols were identified, a new card was placed directly over the previous one by the examiner. This procedure was continued for 60 seconds and timed with a digital stopwatch. At the end of the one minute test period, the number of cards completed as well as the number and type of errors committed were recorded on a pre-printed recording form. Types of errors included additions, omissions, reversals, and discrimination errors. Data from subjects committing five or more errors on any test condition were excluded from the final data analysis.
This was done in order to be consistent with the protocol used by Argenbright and Beaudoin\textsuperscript{11} and Mackner and Onorato\textsuperscript{13}.

Following the response time testing of the three target types, accommodative facility was sampled for each subject using the previously mentioned modified Landolt C cards as a target. This was also done to ensure internal consistency with previous researchers\textsuperscript{11,13} and to gather additional normative lens rock data. Subject posture, viewing distance, and illumination were the same as in the previous response time testing. The accommodative flippers used were a power of $+/− 2.00$ diopters and were manufactured by the Bernell Corporation.

In order to insure the validity of the lens rock data, each subject was first tested for suppression through both the $+2.00$ and $-2.00$ sides of the flipper. This was accomplished by having the subject wear a pair of polaroid glasses, look through each side of the flipper, and read aloud letters (20/50 visual acuity demand at 40 cm) through a polaroid bar reader. Any subject demonstrating suppression or unable to clear both sides of the flipper was dismissed from the study. For those subjects who could clear both sides of the flipper and did not exhibit suppression, a lens rock instructional set was given along with flipper practice (see Appendix E). Each subject was tested with lens rock for 60 seconds, after which the number of cards completed and the number and types of errors committed was recorded.

Following the lens rock test phase, each subject was again checked for suppression through both sides of the flipper. As before, data from subjects demonstrating suppression at this point was omitted from the final lens rock data analysis.
RESULTS

Table 1 is a list of the mean speed at which each of the three target stimuli were called out by the first and fourth grade subjects.

<table>
<thead>
<tr>
<th>Target</th>
<th>First Grade (N=81)</th>
<th>Fourth Grade (N=83)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean SPC   SD</td>
<td>Mean SPC   SD</td>
</tr>
<tr>
<td>1. Numbers</td>
<td>2.67 +/- 0.43</td>
<td>1.78 +/- 0.31</td>
</tr>
<tr>
<td>2. Letters</td>
<td>2.86 +/- 0.84</td>
<td>1.83 +/- 0.35</td>
</tr>
<tr>
<td>3. Landolt C's</td>
<td>3.52 +/- 0.55</td>
<td>2.85 +/- 0.45</td>
</tr>
</tbody>
</table>

First graders were fastest calling out the numbers, and slowest at identifying the Landolt C's. All between targets comparisons using a one factor ANOVA repeated measures demonstrated a significant difference in naming speed (Scheffe F-test: p<0.05). The numbers were called out 0.19 seconds per card (SPC) faster than the letters and 0.85 SPC faster than the C's; the letters were named 0.66 SPC faster than the C's.

Fourth graders were also fastest calling out the numbers, and slowest calling out the Landolt C's. There was no significant difference in fourth grade naming speed between the numbers and letters. However, both numbers and letters were named significantly faster than the Landolt C's (Scheffe F-test: p<0.05). The numbers were named 1.07 SPC faster than the C's and the letters were named 1.02 SPC faster than the C's.
The order in which the three test conditions were presented to the subjects was randomized. Analysis of test order results yielded no statistically significant effects on performance with either first or fourth graders.

Table 2 is a list of the mean errors for each grade and each of the three target stimuli for all test conditions except lens rock.

### TABLE 2
ERRORS PER SUBJECT (EPS)

<table>
<thead>
<tr>
<th>Target</th>
<th>First Grade (N=81)</th>
<th>Fourth Grade (N=83)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean EPS  SD</td>
<td>Mean EPS  SD</td>
</tr>
<tr>
<td>1. Numbers</td>
<td>0.57 +/- 1.05</td>
<td>0.17 +/- 0.64</td>
</tr>
<tr>
<td>2. Letters</td>
<td>0.67 +/- 0.99</td>
<td>0.23 +/- 0.69</td>
</tr>
<tr>
<td>3. Landolt C's</td>
<td>0.95 +/- 1.22</td>
<td>0.52 +/- 0.86</td>
</tr>
</tbody>
</table>

First graders made the fewest errors naming the numbers, and the most errors naming the Landolt C's. However, the differences were not significant (Scheffe: p>0.05).

The fourth graders also made the fewest errors naming the numbers, and the most errors naming the Landolt C's. With the ANOVA, there was no difference in errors between the number and letter targets, but there were significantly more naming errors with Landolt C's than with naming letters or numbers (Scheffe: p≤0.05). With Landolt C's versus numbers, 0.35 more errors per subject (EPS) were made naming the C's. Compared to letters, 0.29 more EPS were made naming the C's.
Table 3 is a comparison of the mean naming speed and errors per subject for two different test conditions using the same target stimuli, Landolt C’s. In condition 1 no lenses were used, whereas subjects were required to turn a +/- 2.00 D flipper after each target card in condition 2.

**TABLE 3**
**LANDOLT C’S: WITH AND WITHOUT FLIPPERS**

<table>
<thead>
<tr>
<th>Test Condition</th>
<th>N</th>
<th>Mean SPC SD</th>
<th>Mean EPS SD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>First Graders</td>
<td></td>
</tr>
<tr>
<td>1. Landolt C’s only</td>
<td>81</td>
<td>3.52 +/- 0.55</td>
<td>0.95 +/- 1.22</td>
</tr>
<tr>
<td>2. C’s with lens rock</td>
<td>72</td>
<td>7.57 +/- 2.33</td>
<td>1.06 +/- 1.22</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fourth Graders</td>
<td></td>
</tr>
<tr>
<td>1. Landolt C’s only</td>
<td>83</td>
<td>2.85 +/- 0.45</td>
<td>0.52 +/- 0.86</td>
</tr>
<tr>
<td>2. C’s with lens rock</td>
<td>68</td>
<td>5.44 +/- 1.38</td>
<td>0.60 +/- 0.88</td>
</tr>
</tbody>
</table>

SPC= seconds per card     EPS= errors per subject

For the first grade data, a paired t-test (2-tail) indicated that the difference between the two test conditions is highly significant (p≤0.0001). There was a mean difference between the conditions of 4.06 SPC, indicating that the lens rock portion with the C’s as target stimuli required 4.06 seconds more naming time per card than the C’s alone without any lenses. There were no significant error differences between the two conditions.

For the fourth grade data, a paired t-test (2-tail) indicated that the difference between the two conditions is also highly significant (p≤0.0001). There was a mean difference of 2.61 SPC, indicating that the lens rock portion took 2.61 seconds per card longer than just the C’s alone. As with the first graders, there was no significance to the difference in errors between the two conditions.
TABLE 4

FIRST GRADE
Correlation Matrix for Variables: X₁ ... X₄

<table>
<thead>
<tr>
<th></th>
<th>NUMBERS</th>
<th>LETTERS</th>
<th>LAND. C'S</th>
<th>+/-ROCK</th>
</tr>
</thead>
<tbody>
<tr>
<td>NUMBERS</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LETTERS</td>
<td>.605</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LAND. C'S</td>
<td>.538</td>
<td>.458</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>+/-ROCK</td>
<td>.419</td>
<td>.378</td>
<td>.292</td>
<td>1</td>
</tr>
</tbody>
</table>

Note: 11 cases deleted with missing values.

Table 4 is a first grade correlation matrix table for all four test conditions. All correlation values were calculated from seconds per card data. The highest correlation (.605) was between number and letter naming speed. The next highest (.538) was between number and Landolt C speed, followed by letter and Landolt C speed (.458). Error correlations for all four target conditions ranged between zero and 0.400.

TABLE 5

FOURTH GRADE
Correlation Matrix for Variables: X₁ ... X₄

<table>
<thead>
<tr>
<th></th>
<th>NUMBERS</th>
<th>LETTERS</th>
<th>LAND. C'S</th>
<th>+/-ROCK</th>
</tr>
</thead>
<tbody>
<tr>
<td>NUMBERS</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LETTERS</td>
<td>.837</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LAND. C'S</td>
<td>.561</td>
<td>.622</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>+/-ROCK</td>
<td>.436</td>
<td>.549</td>
<td>.362</td>
<td>1</td>
</tr>
</tbody>
</table>

Note: 15 cases deleted with missing values.

Table 5 is a fourth grade correlation matrix table for all four test conditions. The highest correlation (.837) was found between number and letter naming speed. The next highest correlation (.622) was between
letter and Landolt C naming speed, followed by a .561 correlation between numbers and Landolt C's. Error correlations between conditions was highest between numbers and letters (.604), followed by letters and C's (.439), and numbers and C's (.372).

**TABLE 6**

**COMPARISON OF FIRST VS. FOURTH GRADES**

<table>
<thead>
<tr>
<th>Variable</th>
<th>1st Grade</th>
<th>4th Grade</th>
<th>Mean Diff.</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Number cards: speed</td>
<td>2.67 SPC</td>
<td>1.78 SPC</td>
<td>0.89 SPC</td>
<td>.0001</td>
</tr>
<tr>
<td>2. Letter cards: speed</td>
<td>2.86 &quot;</td>
<td>1.83 &quot;</td>
<td>1.03 &quot;</td>
<td>.0001</td>
</tr>
<tr>
<td>3. Landolt C's: speed</td>
<td>3.52 &quot;</td>
<td>2.85 &quot;</td>
<td>0.67 &quot;</td>
<td>.0001</td>
</tr>
<tr>
<td>4. Lens rock: speed</td>
<td>7.57 &quot;</td>
<td>5.44 &quot;</td>
<td>2.13 &quot;</td>
<td>.0001</td>
</tr>
<tr>
<td>5. Numbers: errors</td>
<td>0.57 EPS</td>
<td>0.17 EPS</td>
<td>0.40 EPS</td>
<td>.0036</td>
</tr>
<tr>
<td>6. Letters: errors</td>
<td>0.67 &quot;</td>
<td>0.23 &quot;</td>
<td>0.44 &quot;</td>
<td>.0012</td>
</tr>
<tr>
<td>7. Landolt C's: errors</td>
<td>0.95 &quot;</td>
<td>0.52 &quot;</td>
<td>0.43 &quot;</td>
<td>.0095</td>
</tr>
<tr>
<td>8. Lens rock: errors</td>
<td>1.06 &quot;</td>
<td>0.60 &quot;</td>
<td>0.46 &quot;</td>
<td>.0068</td>
</tr>
</tbody>
</table>

SPC= seconds per card      EPS= errors per subject

Table 6 is a listing of the mean results for each testing condition and is separated into columns by grade to demonstrate differences in performance of the fourth graders versus the first graders. In comparing between the grades for the number targets, the fourth graders were faster than the first graders by a mean of 0.89 seconds per card, which was highly significant (p=0.0001) according to a 2-tailed t-test. The first graders made a mean 0.40 more errors per subject than the fourth graders with the number cards (p=0.0036).

With the letter targets, the fourth graders were faster than the first graders by a mean of 1.03 seconds per card (p=0.0001). The first graders made a mean 0.44 errors per subject more than the fourth graders with the letter cards (p=0.0012).
With the Landolt C targets, the fourth graders were faster than the first graders by a mean of 0.67 seconds per card, which again was highly significant according to a 2-tailed t-test ($p=0.0001$). The first graders made a mean 0.44 errors per subject more than the fourth graders for the Landolt C cards, also a highly significant difference ($p=0.0001$).

For the lens rock condition, the fourth graders were faster than the first graders by 2.13 seconds per card, a highly significant difference ($p=0.0001$). The first graders made a mean 0.46 errors per subject more than the fourth graders during the lens rock, which again is a significant difference ($p=0.0068$).

**TABLE 7**

**FIRST GRADE: BETWEEN SCHOOLS DIFFERENCES**

<table>
<thead>
<tr>
<th>School</th>
<th>N</th>
<th>Numb</th>
<th>Lett</th>
<th>C's</th>
<th>Rock</th>
<th>Numb</th>
<th>Lett</th>
<th>C's</th>
<th>Rock</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP</td>
<td>22</td>
<td>2.47</td>
<td>2.46</td>
<td>3.21</td>
<td>7.26</td>
<td>0.27</td>
<td>0.23</td>
<td>0.46</td>
<td>0.30</td>
</tr>
<tr>
<td>ES</td>
<td>11</td>
<td>2.79</td>
<td>2.76</td>
<td>3.43</td>
<td>7.03</td>
<td>1.00</td>
<td>0.82</td>
<td>1.91</td>
<td>3.14</td>
</tr>
<tr>
<td>JG</td>
<td>21</td>
<td>2.59</td>
<td>2.83</td>
<td>3.54</td>
<td>6.97</td>
<td>0.38</td>
<td>0.90</td>
<td>0.90</td>
<td>0.75</td>
</tr>
<tr>
<td>HP</td>
<td>12</td>
<td>2.73</td>
<td>2.95</td>
<td>3.44</td>
<td>8.89</td>
<td>0.50</td>
<td>0.42</td>
<td>0.42</td>
<td>0.75</td>
</tr>
<tr>
<td>HC</td>
<td>15</td>
<td>2.94</td>
<td>3.48</td>
<td>4.07</td>
<td>8.05</td>
<td>1.00</td>
<td>1.07</td>
<td>1.47</td>
<td>1.85</td>
</tr>
</tbody>
</table>

Table 7 separates the mean results for first grade subjects by target type, test condition, grade, and by the school from which the data was collected. A one factor ANOVA was used to evaluate the school results to determine if there were any differences in performance between schools. The following charts and graphs illustrate differences between schools; below each is a listing of those found to be significant according to the Scheffe F-test ($p<0.05$).
CHART 1
FIRST GRADE: BETWEEN SCHOOLS COMPARISONS OF SPEED

SECONDS PER CARD

TARGET STIMULI

Numbers Letters Landolt C's

4.2----------~--------~------~
4
3.8
3.6--
3.4--
3.2--
3
2.8
2.6
2.4
2

Significant Differences (Scheffe F-test: p<0.05)

Numbers: SP 0.47 SPC faster than HC
Letters: SP 1.02 SPC faster than HC
Landolt C's: ES 0.64 SPC faster than HC
JG 0.52 SPC faster than HC
HP 0.63 SPC faster than HC
SP 0.86 SPC faster than HC
CHART 2
FIRST GRADE: BETWEEN SCHOOLS COMPARISON OF ERRORS

Significant Differences (Scheffe F-test: p<0.05)

Numbers: none
Letters: none
Landolt C's: ES 1.49 EPS more than HP
ES 1.46 EPS more than SP
**Significant Differences (Scheffe F-test: p<0.05)**

For lens rock naming speed, no significant differences were found between schools.

**Chart 3**

**First Grade: Between Schools Comparison of Lens Rock Speed**

**Chart 4**

**First Grade: Between Schools Comparison of Lens Rock Errors**
Significant Differences (Scheffe F-test: p<0.05)

ES 2.39 EPS more than JG  
HC 1.10 EPS more than JG  
ES 2.39 EPS more than HP  
HC 1.10 EPS more than HP  
ES 2.84 EPS more than SP  
HC 1.55 EPS more than SP

Table 8 separates the mean results for forth grade subjects by target type, test condition, grade, and by the school from which the data was collected. A one factor ANOVA was used to evaluate the school results to determine if there were any differences in performance between schools. The following charts and graphs illustrate differences between schools; below each is a listing of those found to be significant according to the Scheffe F-test (p<0.05).

### TABLE 8
**FOURTH GRADE: BETWEEN SCHOOLS DIFFERENCES**

<table>
<thead>
<tr>
<th>School</th>
<th>Numb</th>
<th>Lett</th>
<th>C’s</th>
<th>Rock</th>
<th>Numb</th>
<th>Lett</th>
<th>C’s</th>
<th>Rock</th>
</tr>
</thead>
<tbody>
<tr>
<td>JG</td>
<td>1.70</td>
<td>1.80</td>
<td>2.71</td>
<td>4.94</td>
<td>0.04</td>
<td>0.04</td>
<td>0.11</td>
<td>0.70</td>
</tr>
<tr>
<td>HP</td>
<td>1.80</td>
<td>1.82</td>
<td>2.83</td>
<td>5.74</td>
<td>0.15</td>
<td>0.15</td>
<td>0.82</td>
<td>0.44</td>
</tr>
<tr>
<td>HC</td>
<td>1.82</td>
<td>1.84</td>
<td>2.94</td>
<td>5.54</td>
<td>0.14</td>
<td>0.19</td>
<td>0.33</td>
<td>0.56</td>
</tr>
<tr>
<td>ES</td>
<td>1.88</td>
<td>1.86</td>
<td>3.11</td>
<td>5.71</td>
<td>0.75</td>
<td>1.25</td>
<td>1.38</td>
<td>1.33</td>
</tr>
</tbody>
</table>
For the naming speed of number, letter, and Landolt C targets, there were no significant differences found between schools.
**CHART 6**
FOURTH GRADE: BETWEEN SCHOOLS COMPARISON OF ERRORS

Significant Differences (Scheffe F-test: p<0.05)

**Numbers:**
- ES 0.71 EPS more than JG

**Letters:**
- ES 1.06 EPS more than HC
- ES 1.21 EPS more than JG
- ES 1.10 EPS more than HP

**Landolt C's:**
- ES 1.04 EPS more than HC
- ES 1.26 EPS more than JG
- HP 0.70 EPS more than JG
Significant Differences (Scheffe F-test; p<0.05)

For lens rock naming speed and lens rock errors, there were no significant differences found between schools.
DISCUSSION

When comparing the response times for each target type, both the first and fourth grade subjects were faster at naming the numbers than either the letter or modified Landolt C targets. We believe that both groups responded to the numbers faster than the letters because of the fewer possibilities presented by the numbers. Although the difference between numbers and letters for the fourth grade subjects was not found to be significant, it was for the first grade subjects. This greater difference in response times for the first graders is believed to be due to the fact that letters involve a greater directionality demand than do numbers, and that children of this age have not been exposed to letters as much as numbers. By the fourth grade, however, we would expect that familiarity with letters should be equal to or greater than numbers.

As was expected, response times for the modified Landolt C targets were significantly slower than either the numbers or letters for both groups. This result was predicted due to the children's unfamiliarity with the Landolt C's and the fact that these targets have fewer external identifying shape cues than numbers or letters.

Both groups committed the fewest errors with the number targets and the most errors with the Landolt C's. For the first grade subjects, the difference between errors for the three target types was not statistically significant. For the fourth grade subjects, however, error differences between the three targets were statistically significant. These findings are consistent with the fact that first graders were somewhat
inexperienced with all three target types whereas the fourth graders were unfamiliar only with the novel Landolt C targets.

In a comparison of modified Landolt C reaction times with and without the lens rock, the first grade and fourth grade subjects took an average of 4.06 and 2.61 seconds longer respectively per card to identify the Landolt C's through the lenses than without the lenses. It is presumed that the reaction time difference between Landolt C conditions with and without the lens rock represents the amount of time necessary for the accommodative response and incongruent posturing between accommodation and convergence to occur, since automaticity has been factored out.

According to Adler\(^1\), the total time it takes an adult to react and respond to an accommodative stimulus ranges from 0.92 to 1.0 seconds and is independent of the amplitude of the accommodative demand. Our results indicate that it took 4.06 seconds for the first graders and 2.61 seconds for the fourth graders to accommodate to a 2.5 diopter stimulus. There are many possible reasons why the accommodation times from our data are so much slower than that reported by Adler. First, Adler's data was obtained from an adult population, who may accommodate faster and more accurately than children. Also, the data reported by Adler was obtained from precise objective measuring techniques utilizing a Badal optometer, whereas our results were inferred from subjective responses. Finally, Adler measured reaction time and accommodative response separately, while our testing method included a vergence response component as well as an accommodative one. Although the vergence demand remained constant in our study, the pairing or posture between
accommodation and convergence was altered during the lens rock phase. This incongruent pairing might be influenced by a patient's AC/A ratio and positive and negative fusional vergence reserves.

When comparing the response time performance between grades, the fourth grade subjects were faster than the first grade subjects for all three target conditions. The greatest difference was found for the letter targets, with the fourth graders being a mean 1.03 seconds per card faster than the first graders. This difference might be explained by the fact that in first grade many children are still somewhat unfamiliar with the letters of the alphabet, whereas by the fourth grade, the majority of students are proficient at letter recognition.

The next largest difference was found with the number targets, with the fourth graders being an average 0.89 seconds per card faster than the first graders. Again, this difference between grades can be attributed to the increased familiarity of fourth graders to the targets.

The smallest difference in response times between grades was found with the modified Landolt C targets. The fourth grade subjects were only 0.67 seconds faster per card than the first graders. Since the Landolt C targets were equally unfamiliar to both groups, the number/letter familiarity difference between first and fourth grades was presumably factored out. Thus, the difference in response times for the Landolt C's could be attributed to a maturation difference in the cognitive processing and verbal-motor ability between the first and fourth grades.

If we consider the 0.67 seconds per card as a baseline value for the amount of time it takes for cognitive and verbal-motor processing to occur, we can subtract this number from the mean difference between
grades for the other two targets and predict a time to represent the visual-verbal response time, or automaticity. When this is performed for the number targets, we arrive at 0.22 seconds per card which can be attributed to automaticity. For letter targets, the automaticity factor is calculated to be 0.36 seconds per card. These numbers indeed support our hypothesis that the unique Landolt C targets may be a better controller of automaticity than either numbers or letters when testing school age children.

When comparing the correlation between target types, the strongest correlation (.837) was found between the number and letter targets for fourth grade subjects. A correlation of 0.6 between two variables represents a reasonably strong relationship\(^{15}\) and indicates that the two test conditions are measuring similar performance variables, visual-verbal response time of familiar targets. With this high correlation between the two target types, we could predict how a fourth grade subject would perform with letter targets from their performance with number targets and vice versa. For familiar compared to unfamiliar targets (numbers vs. Landolt C's and letters vs. Landolt C's), this relationship is not as predictable. The lower correlations and unaccounted for variance found between these conditions indicates that factors other than visual-verbal response time are affecting subject performance. When other factors are involved, performance cannot be predicted for one target type based on the performance with another.

In a previous study, Argenbright and Beaudoin found a significant difference in performance between schools, with poorer performances coming from schools located in more rural areas. Although a difference
between schools was found in this study, there was no correlation between performance and school location. It should be noted that our individual school sample sizes were in some cases not large enough for reliable between schools statistical analysis.

Our response time results indicate that first grade performance did not differ significantly between four of the five schools tested. However, the remaining school (HC), performed significantly poorer in all three test conditions when compared with the other schools. This pattern did not hold true for errors in which no significant difference between any of the schools occurred for first grade subjects. For fourth grade subjects, no significant difference between schools was found for response times although the ES fourth graders committed significantly more errors than the other schools. For the lens rock condition, no difference in response times was noted between schools. However, two of the schools (ES, HC), committed significantly more errors than the others.

We feel the poor performance by the HC first grade subjects may be partially attributed to examiner performance as HC was the first group tested. The examiners became more familiar and comfortable with the testing procedure at the subsequent schools. Consequently, results show a greater variance for this first group than for any of the others.

For the fourth graders, all between school differences disappear when ES is removed except for Landolt C errors, which is primarily due to HC being high. The poor mean performance of ES may possibly be an artifact of a low sample size. At ES we tested only 8 fourth grade subjects, whereas the mean fourth grade sample size of the other three schools was 25 subjects.
In order to increase testing efficiency and achieve a relatively large total sample size, three examiners were employed. Although the instructions, protocol, and testing environment were standardized as much as possible, there are several examiner related factors that may have contributed to increased variability of this study. Potential confounders include: tone of voice, posture, facial expression, age and gender of the examiner, etc.

Several non-experimental factors may have also played a role in increasing test variability. The time of day at which the test was administered is important because motivation, attention, fatigue, hunger, and restlessness of school children vary throughout the day and may effect perceptual test results. Since our testing was done during pre-scheduled school vision screenings, we were unable to control the specific time at which all subjects were tested. Most subjects were tested before noon, although approximately 30% of the subjects were tested after the lunch break.

It is possible that some subjects may have been previously exposed to the modified Landolt C targets and our testing protocol prior to this study. Some of our fourth grade subjects may have also been first grade subjects with Argenbright and Beaudoin three years earlier. It is also possible that some of the subjects gained greater familiarity with the targets and protocol by virtue of having observed their classmates being tested while waiting in line to be tested. The test environment was more crowded at some schools than others. Such prior exposure to the targets and/or familiarity with the testing protocol could have enhanced subject performance.
Anxiety as a result of the testing procedure is another factor which may have affected subject performance. This varies greatly from subject to subject, with some viewing tests as a challenge to be conquered, while others may be apprehensive to any type of testing. The particular attitude, environment, and philosophy of a school may influence subjects' perceptions of tests, as some schools may emphasize test performance more than others.

The final objective of our study was to contribute additional normative facility data to the pool of Mackner and Onorato and Argenbright and Beaudoin using the +/- 2.00 diopter lens rock and modified Landolt C targets. The following table is a summary of the results from the three studies:

<table>
<thead>
<tr>
<th>Investigator</th>
<th>Grade</th>
<th># of Schools</th>
<th>N</th>
<th>Lens</th>
<th>Mean CPM</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bricker, Gaume &amp; Gilbert (1991)</td>
<td>1st</td>
<td>5</td>
<td>81</td>
<td>none</td>
<td>8.71</td>
<td>1.24</td>
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<tr>
<td></td>
<td>4th</td>
<td>4</td>
<td>83</td>
<td>none</td>
<td>10.80</td>
<td>1.79</td>
</tr>
<tr>
<td></td>
<td>1st</td>
<td>5</td>
<td>72</td>
<td>+/- 2.00</td>
<td>4.33</td>
<td>1.32</td>
</tr>
<tr>
<td></td>
<td>4th</td>
<td>4</td>
<td>68</td>
<td>+/- 2.00</td>
<td>5.85</td>
<td>1.42</td>
</tr>
</tbody>
</table>

Mackner & Onorato (1989)

<table>
<thead>
<tr>
<th></th>
<th>Grade</th>
<th># of Schools</th>
<th>N</th>
<th>Lens</th>
<th>Mean CPM</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>1</td>
<td>22</td>
<td>none</td>
<td></td>
<td>7.00</td>
<td>1.52</td>
</tr>
<tr>
<td>4th</td>
<td>1</td>
<td>49</td>
<td>none</td>
<td></td>
<td>10.54</td>
<td>1.69</td>
</tr>
<tr>
<td></td>
<td>1st</td>
<td>1</td>
<td>22</td>
<td>+/- 2.00</td>
<td>3.50</td>
<td>1.33</td>
</tr>
<tr>
<td></td>
<td>4th</td>
<td>1</td>
<td>49</td>
<td>+/- 2.00</td>
<td>7.37</td>
<td>1.92</td>
</tr>
</tbody>
</table>

Argenbright & Beaudoin (1987)

The cards only condition was not performed.

<table>
<thead>
<tr>
<th></th>
<th>Grade</th>
<th># of Schools</th>
<th>N</th>
<th>Lens</th>
<th>Mean CPM</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>4</td>
<td>33</td>
<td>+/- 2.00</td>
<td>4.86</td>
<td>1.18</td>
<td></td>
</tr>
<tr>
<td>4th</td>
<td>4</td>
<td>34</td>
<td>+/- 2.00</td>
<td>7.28</td>
<td>1.56</td>
<td></td>
</tr>
</tbody>
</table>
Comparing the results of the first grade subjects performing the lens rock, our findings fell between those of the other two studies. For the cards only phase, our results fell just outside one standard deviation of Mackner and Onorato (Argenbright and Beaudoin did not perform this test). It is possible that the difference in the first grade lens rock results between the two studies may be due to the small sample size of Mackner and Onorato.

For the fourth grade students, less difference between the studies was anticipated because it was assumed that fourth graders would be less variable than the first graders in their visual-verbal skills. The mean cycles per minute for our fourth grade subjects is lower for the lens rock than that found by either of the previous two studies. When comparing our cards only response time results with those of Mackner and Onorato, the results are very close. This indicates that the lens rock testing protocol must have been at least partially responsible for the difference in accommodative facility results.

We believe that fourth grade subjects in previous studies may have performed the lens rock faster than our subjects because of their greater exposure to the Landolt C targets and prior practice with the lens flippers. In our study, subjects were exposed to the Landolt C targets only once prior to performing the lens rock, in addition to having no prior exposure to a lens flipper. Mackner and Onorato employed Landolt C targets in all five test conditions of their study and four of the five conditions utilized some type of lens flipper. Similarly, lens flippers and Landolt C targets were used in two of the three testing conditions in Argenbright and Beaudoin's study.
CONCLUSIONS

Based on the results of this study, several conclusions can be made: (1) Data obtained from adult relative response time test studies cannot be directly applied to school age children; (2) All relative response time tests without an age appropriate automaticity baseline should be suspect; (3) Visual-verbal response time norms for various targets need to be established for every age group; and (4) Modified Landolt C targets provide a better control of automaticity than conventional number and letter targets when using relative response time tests with school age children.

Another advantage of the modified Landolt C's is that they have very few shape cues to aid in identification, and therefore require more precise motor responses by the subject. There are disadvantages to the Landolt C target, however, which are that they have few possibilities (only four), don't represent a true reading task, and may be too difficult for some of the younger children.

There are several related topics that could be addressed in future research: (1) Develop automaticity baseline norms for various targets. Once these norms are established, they can be applied to the scoring and pass/fail criteria of relative response time tests such as the lens rock, prism rock, DEM and KD. This will allow the practitioner to know whether his patient is failing a RRTT due to poor automaticity rather than the actual visual factor supposedly being tested. (2) Explore the test/retest reliability for various targets. (3) Determine at what age(s) automaticity factors reach minimum influence and relative response times plateau at an adult-like level, noting any differences between sexes. (4) Find out
why the Landolt C targets are so difficult for young children. (5) Develop a computer program that could flash targets at the same location on a screen under the control of an examiner. Such an instrument would allow a more precise presentation of targets and control of variables in the protocol to norm relative response times.

Another suggested topic of future research would be to gather monocular accommodative facility data using the same targets and protocol as that used in this study. Our results indicate that first graders seem to have a slower accommodative and/or accommodative-convergence response than do fourth graders. By comparing the monocular and binocular facility data, it could be determined whether this difference between grades is a result of purely accommodative variables or a binocular phenomenon, in which case the difference would be expected to disappear with monocular testing.
APPENDIX A
P.U.C.O. VISION SCREENING CRITERIA FOR REFERRAL

A. * VISUAL ACUITY
   1. Near or Far                             20/30 or poorer, either eye

B. * REFRACTIVE ERROR
   1. Hyperopia                               +1.50 D or more
   2. Myopia                                  -0.75 D or more w/ acuity loss
   3. Astigmatism                             ±1.00 D or more
   4. Anisometropia                           ±1.00 D or more

C. * TWO-EYED COORDINATION
   1. At Distance (20 feet)                   Any Tropia
      a. Tropia                                Any Tropia
      b. Esophoria                             5Δ or more
      c. Exophoria                             5Δ or more
      d. Hyperphoria                           2Δ or more
   2. At Near (16 inches)                     Any Tropia
      a. Tropia                                Any Tropia
      b. Esophoria                             5Δ or more
      c. Exophoria                             10Δ or more
      d. Hyperphoria                           2Δ or more

D. OCULAR HEALTH                             Any verified pathology or medical anomaly of the eye and/or adnexa

E. OCULAR PRESSURE (if tested)               26 mm Hg or greater
   1. Measured IOP                           6 mm Hg or greater
   2. IOP (R) - IOP (L)                      6 mm Hg or greater

F. BLOOD PRESSURE (if tested)                90 mm Hg or greater
   1. Diastolic                                90 mm Hg or greater

*Categories A, B, C tested with habitual corrective lenses in place.
APPENDIX C

DEMONSTRATION OF EACH TARGET TYPE

Demonstration of number targets:
"I'm going to be showing you some cards with numbers on them. Each card will have two numbers on it. Please call out each number separately as I place a card in front of you."

The examiner began placing demonstration cards before the subject until all possible number targets were shown.

Demonstration of letter targets:
"I'm going to be showing you some cards with letters on them. Each card will have two letters on it. Please call out each letter separately as I place a card in front of you."

The examiner began placing demonstration cards before the subject until all possible number targets were shown.

Demonstration of Modified Landolt C targets:
"The targets we will be using for this test are rings which have gaps or openings in them."

The examiner presented each of the four Modified Landolt C demonstration targets to the subject and assisted them in correctly identifying the direction of the target openings.

Note: Each subject was allowed to use his/her preferred way of responding to the targets. Some of the correct responses included:

- up, top
- down, bottom
- both, up and down, top and bottom
- none, zero, O, circle

"Please call out which way the gaps or openings in the rings are pointing as I place a card in front of you."
APPENDIX D
RESPONSE TIME INSTRUCTIONAL SET

Instructions for response time testing:

"The purpose of this test is to see how many (numbers, letters, rings) you can correctly identify in one minute. As you can see, they are smaller than those used in the demonstration."

_The examiner placed a sample test card before the subject._

"I will be placing the cards in front of you one at a time. As soon as I put down the next card, I would like you to call out each (number, letter, direction the gaps are pointing)."

"Call out targets as quickly as possible. If you call out a target incorrectly or don't know what it is, don't hesitate or go back to correct it. Just continue to the next target or card until you are told to stop."

"Do you understand?"

_Instructions were repeated as necessary until the subject fully understood the protocol before testing began._
APPENDIX E
LENS ROCK INSTRUCTIONAL SET

Instructions for lens rock testing:

"The purpose of this test is to see how many times you can flip these lenses and identify rings in one minute."

"After the rings on each card become clear and single through the lenses, call out which way you think the gaps are pointing."

"Once you call out each pair of targets, you should immediately flip the lenses and I will place a new card in front of you."

The examiner showed the subject how to hold the flippers in his/her dominant hand and how to flip the lenses quickly and easily.

"Call out targets and flip the lenses as quickly as possible. If you call out a target incorrectly or don't know what it is, don't hesitate or go back to correct it. Just continue to the next target or card until you are told to stop."

"Do you understand?"

Instructions were repeated as necessary until the subject fully understood the protocol and was comfortable with the flippers before testing began.

2. King AT, Devick S. The proposed King-Devick Test and its relation to the Pierce Saccade Test, and reading levels. Senior research project, Illinois College of Optometry, 1976.


