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Developmental change in the Word Superiority and its correlation with Reading Fluency

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[redacted]
Doctoral Candidate : Nina Glauch

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4/29/2013
Date

DEVELOPMENTAL CHANGES IN WORD SUPERIORITY AND ITS CORRELATION WITH READING FLUENCY

by

Andrea Henninger
&
Nina Glauch

This paper is submitted in partial fulfillment of the requirements for the degree of

Doctor of Optometry

Ferris State University
Michigan College of Optometry
May 2014

DEVELOPMENTAL CHANGES IN WORD SUPERIORITY AND ITS CORRELATION WITH READING FLUENCY

by

Andrea Henninger
&
Nina Glauch

Has been approved
May 2014

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Faculty Course Supervisor

DEVELOPMENTAL CHANGE IN WORD SUPERIORITY AND ITS CORRELATION WITH READING FLUENCY

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______________________________ ______________________________

Doctor of Optometry Candidates

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Date

ABSTRACT

Background: *Normal adult readers are capable of recognizing words in conditions where they are unable to accurately recognize the sequence of letters– termed the word superiority effect (WSE). It is hypothesized that the recognition of words, as opposed to random letter strings, are facilitated by contributions from a well-developed lexical bank thereby producing the WSE. It follows that those readers without an adequately developed lexical bank may fail to show the WSE, and therefore may rely more on letter sequence recognition when recognizing words. This study explored the possible correlation between the emergence of the WSE and reading efficiency in 3rdgrade students.* **Methods**: The visual span was measured for random trigrams and high frequency three letter words in twenty-three 3rd grade students using high contrast (0.8) Courier text presented on an LCD monitor at various eccentricities relative to fixation using the method proposed by Legge et. al. (2007). Reading speed and grade-level reading ability data was collected from school-based assessments (STAR assessments) for each subject. The size of the visual spans for trigrams and words were computed for each subject. The difference in visual spans for trigrams and words was taken as a measure of the magnitude of the Word Superiority Effect (WSE). **Results**: While trigrams were less easily recognized at increasing eccentricities, three lettered words were more consistently identified regardless of eccentricity. Students with greater grade equivalents tended to have larger visual spans for trigrams and words. Those students who were performing above a fourth grade level in school produced results comparable to adult levels. **Conclusion***:* This study demonstrates that the WSE has emerged in third and fourth graders; however, further testing with larger sample sizes across all school grades would need to be conducted to

thoroughly test the interaction between visual span size, the WSE and grade level reading efficiency.

ACKNOWLEDGEMENTS

Dr. Avesh Raghunandan

AND

Riverview Elementary

Table of Contents

List of Tables, Figures, Illustrations, Symbols

Introduction, Background & Literature Review

Learning to read fluently is a process that takes years to develop. Behavioral studies have shown that kindergarteners and early first graders approach words, pronounceable pseudowords, and unpronounceable nonwords letter-by-letter. Over time, fluent readers begin to develop automaticity and begin to process orthographic information pre-lexically. Students first become familiar with letters, then phonetics, and finally the full word. As a student progresses through grade school, they encounter similar letter sequences and words; thereby becoming familiar with their orthographic structure. It is thought that "words, pseudowords, and nonwords are relatively reliably discriminated in typically developing readers by the fourth grade, by which time reading of most high frequency words is thought to be relatively automatized, effortless, and fluent" (Coch, Mitra, and George 2012).

Reading involves many mechanisms and requires an individual to be proficient in not only phonological and linguistic tasks, but also involves accurate perceptual components. Although most students know the alphabet well by the age of six and visual acuities are near adult levels in normal sighted children around the age of seven, efficient reading and sensitivity to orthographic structure takes years throughout elementary school to develop (Coch, Mitra, and George, 2012; Kwon, Legge, and Dubbels, 2007). As reading develops and an individual begins to recognize words, reading becomes more fluent, which saves cognitive resources to be used for further comprehension (Coch, Mitra, and George, 2012).

An individual's visual span, or range of text reliably identified without moving the eyes, also aids in reading efficiency. As an individual develops reading efficiency, their visual span increases as well and is most noted during elementary school. It has been shown that the size of the visual span tends to increase from third grade into adulthood as the reading speed increases. In fact, "a statistically significant 34% to 52% of the variance in reading speed could be accounted for by the size of the visual span." As one fixates, a larger visual span allows a reader to accurately recognize more letters, thereby allowing saccadic movements of greater magnitude, which in turn results in faster reading. Therefore, a child's development of fixation stability, which increases between the ages of four and fifteen years old along with visual span, plays an important factor in reading performance (Kwon, Legge, and Dubbels, 2007).

As a child develops accurate reading skills, their lexical bank also increases. At this point, the reader can determine letters in a sequence based on reading the entire word and pulling orthographic information from memory (Coch, Mitra, and George, 2012). Normal adult readers are quick to recognize letters in pronounceable words while less accurate when identifying letters in strings of nonwords; a process referred to as the word superiority effect (WSE). Additionally, readers are able to process pronounceable nonwords quicker than strings of nonwords, also known as the pseudoword superiority effect (Houpt, Townsend, and Donkin, 2013; Massol, Midgley, Holcomb, and Grainger, 2011). The time it takes an individual to process isolated words is highly correlated with a reader's fluency (Kwon, Legge, and Dubbels, 2007). Studying a reader's reaction time and WSE can provide a "window onto the earliest phases of visual word recognition, involving the processing of prelexical orthographic and phonological information" (Massol, Midgley, Holcomb, and Grainger, 2011). It has been hypothesized that the mechanism underlying the word superiority effect is facilitated by a well-developed lexical bank, which is continually fine-tuned as reading skills develop (Coch, Mitra, and George, 2012). Additionally, pseudoword superiority effect has been shown to be more significant in adults when compared to children, showing that a larger lexical bank may assist even with recognition of letters in pronounceable nonwords (Coch, Mitra, and George, 2012).

As one can imagine, the relationship between letter recognition and word processing is complex; however, a deeper understanding in correlation with development may provide some crucial insight to understanding this relationship and determine what interactions may strengthen or inhibit word processing (Starrfelt, Petersen, and Vangkilde, 2013) and/or reading ability. This study seeks to explore the idea of a top-down lexical view in which the reader determines a correlation between the orthographic stimuli seen with a recognizable element in their lexical bank (Coch, Mitra, and George, 2012). This hypothesis has been proposed to explain the WSE; however, the study investigated the correlation between reading fluency and the size of the visual span. It also investigated the correlation between reading fluency and the magnitude of the WSE. It has been shown that both visual span size and reading speed increases with grade level. Furthermore, it has been hypothesized that the emergence of the WSE is associated with a well-developed lexical bank. Given that reading fluency and the development of efficient lexical processing are intimately related, the hypothesis posed in this study states that there should be a strong correlation between reading fluency and visual span. In addition, it also hypothesized that students with a reading fluency at or above grade level should have larger magnitudes of WSE compared to students with below grade level fluency.

Methodology

Subjects for this study included a total of 23 students; 12 males and 11 females. All students were within the same academic grade level and testing was performed during the last half of third grade and completed within the first half of fourth grade. Subjects' date of birth ranged from 12/2001 and 12/2003, with the two eldest of the group being held back in prior years: one for academic reasons, one for non-academic reasons. All subjects were randomly assigned a testing ID number for data analysis and testing purposes. The document linking the testing

ID number with the student was kept confidential by the principal and accessed by the investigators only to ensure coordination between the subjects' experimental data and their school based results. All subjects were subsequently identified using the testing ID number to ensure confidentiality of the reading assessment data. Written consent was obtained from all subjects parent/guardian prior to testing. Approval for the use of human subjects was granted by the IRB at Ferris State University (appendix 1).

All subjects were visually screened prior to being included in the study (appendix 2). Those currently wearing correction were permitted to do so during all screening and testing. Near visual acuities of the subjects ranged from 20/15 to 20/30. Accurate distance visual acuities were unable to be obtained due to the limitations of the testing site. All students, except for one, were able to obtain global stereopsis; however, there were no identifiable clinical reasoning as to why the individual was not (no strabismus, etc). Local stereopsis ranged from 20 to 200 seconds of arc. Phoric postures ranged from 6 prism diopters esophoria to 6 prism diopters exophoria with the vast majority being between 2-4 prism diopters exophoric. All subjects were determined to have visual systems capable of the visual demands of testing and were subsequently included in the study.

Subjects were given instructions as to how the test was to be conducted and were permitted to take a non-graded pre-test to familiarize themselves with the computer-based experimental protocol. All stimuli were generated using Matlab, and presented on a MacBook Pro LCD monitor using the Psychophysics ToolBox. Testing included positioning each subject 50 cm in front of the MacBook monitor and instructing them to continuously fixate on a central target while trigrams, various combinations of three random lettered nonwords, as well as three lettered words were flashed. All characters were presented as black letters against a bright white background and were rendered using high contrast (0.8), lowercase, Courier font.

The trigrams and three lettered words were presented as three contiguous characters with an inter-letter spacing equivalent to 1.16x the height of a lowercase letter “x”. The angular subtense of the height of the lowercase “x” corresponded to 40 arc minutes at the fixation distance of 50 cm. The trigrams and words were flashed for 100 ms randomly at three contiguous locations from nineteen possible letter positions (nine letter positions on either side of fixation, including fixation, see figure 1 below). However, only 15 letter positions (7 to the left and right of fixation, including fixation) were analyzed because it was only in these letter positions that all 3 letters of the trigrams appeared. Each letter position was sampled 5 times. The frame refresh rate of the monitor was maintained at its default rate of 60 Hz, and verified using a photodetector and oscilloscope. The same was conducted for three lettered words within the students’ known vocabulary, as verified by their teachers.

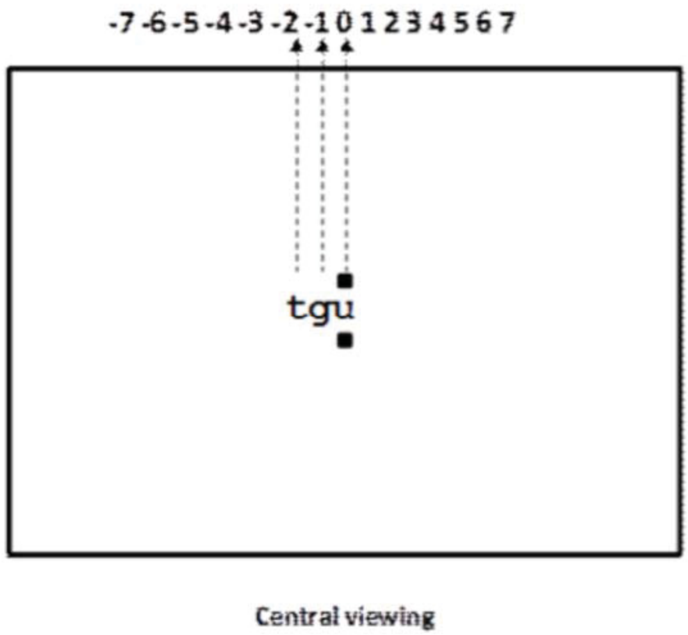

Figure 1: Example of trigrams and their corresponding eccentricities.

Subjects called out the trigram sequence or the word, depending on the paradigm used, while the investigator typed in these responses using a keyboard. No feedback was given to the subjects regarding the accuracy of their responses during the experimental phase of the study. Only those subjects who were able to complete the entire study with proper written parental/guardian consent were included in data analysis. Performance was recorded as proportion correct letter identification at each letter position for trigrams and words.

Data Analysis & Results

Trigrams were less readily recognized with increasing eccentricities, with the most accurate recognition of each non-word sequence being when the sequence was presented centrally (Figures 2 & 3). Many of the students subjectively stated that the letters flashed too quickly to accurately recognize when presented at increasing eccentricities.

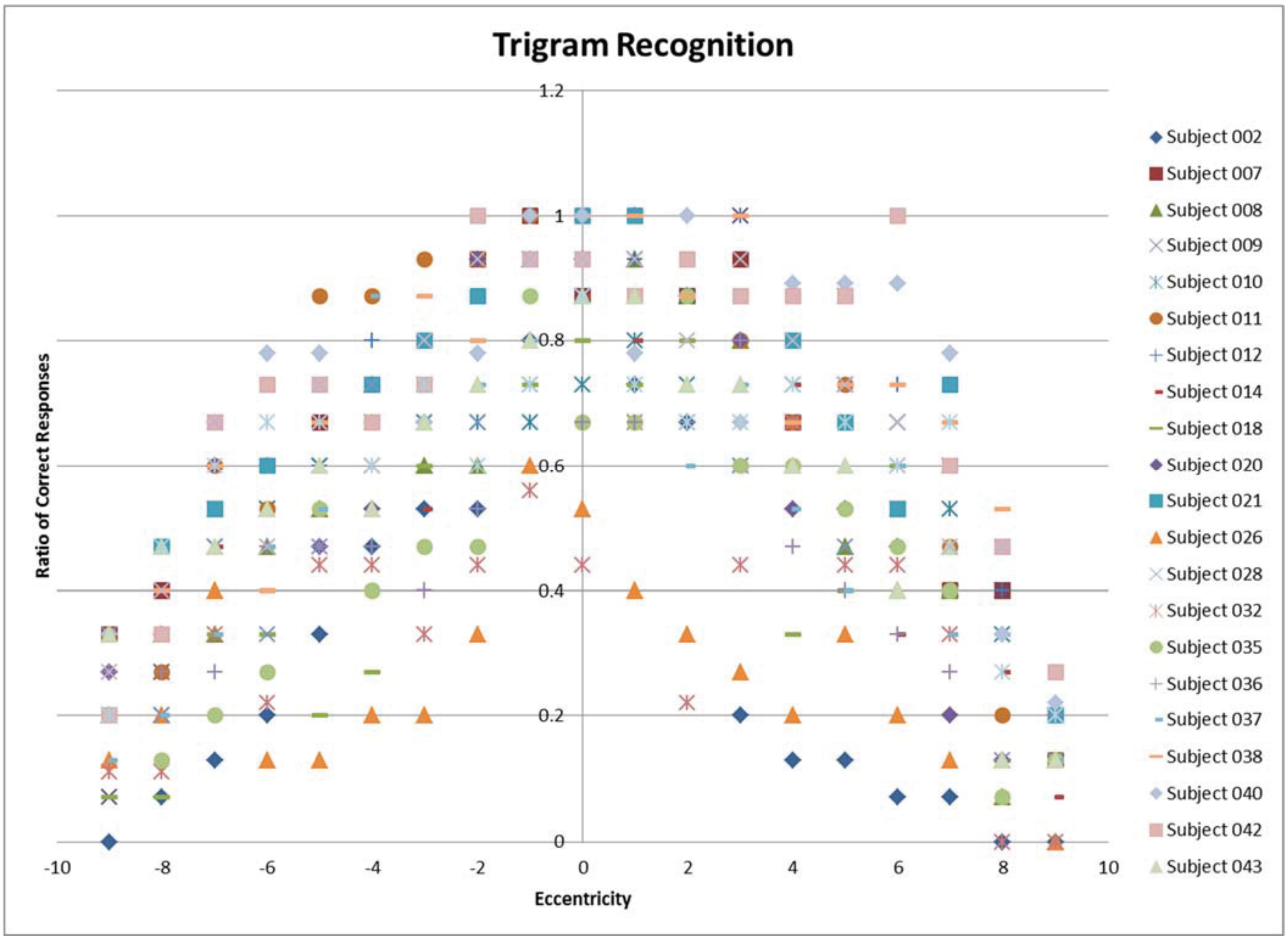

Figure 2: Plots the probability of correct letter recognition for each letter position at and on either side of fixation for each subject. A letter positioned at 0

corresponds to the position occupied by the letter presented at fixation. Positive abscissa values refer to the letter positions to the right of fixation and vice versa.

Randomized three letter words were more easily recognized regardless of eccentricity in comparison to recognizing trigrams (Figure 3), and the subjects also subjectively stated that recognizing three letter words was much easier than recognizing sequences of three letters even at increasing eccentricities. If a subject correctly reported the word, then credit was given for all three letter positions. It also follows that if a subject reported an incorrect word, then no credit was given for the three letter positions. It is evident that word recognition accuracy far exceeded letter sequence accuracy for identical letter positions. This difference reflects the magnitude of the word superiority effect (WSE) (figure 2). The proportion correct was converted to BITS. A proportion correct of 1 represents 4.7 BITS.

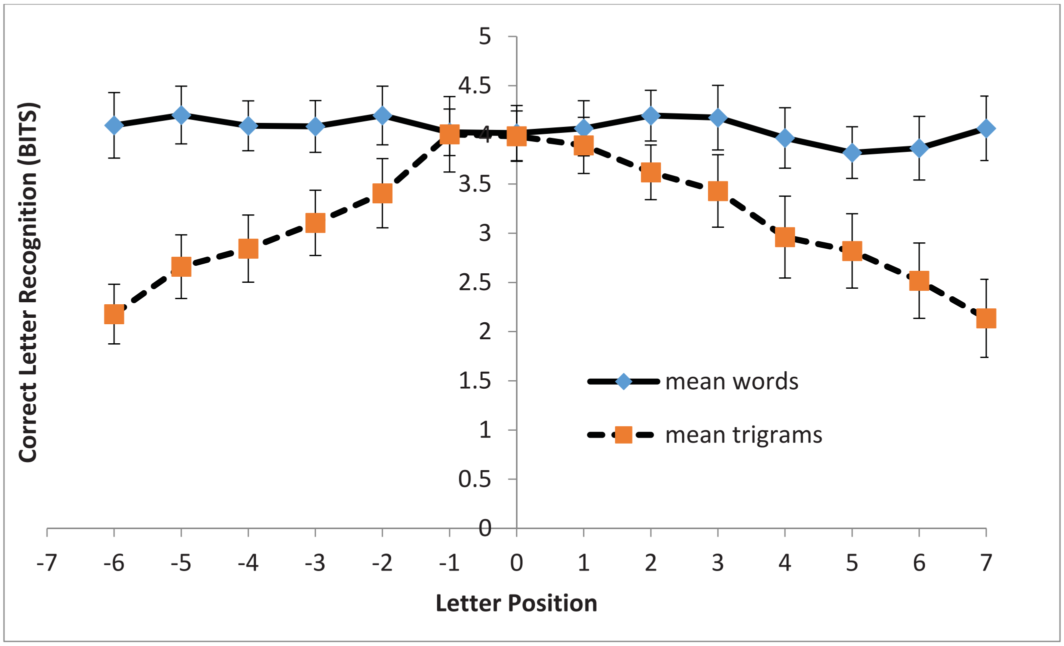

Figure 3: Letter recognition accuracy for trigrams (red squares) and words (diamonds) is plotted for each letter position at and on either side of fixation. Each datum represents the mean (+/- 95% CI) pooled across 23 subjects. Letter recognition accuracy is expressed as BITS.

Information regarding participants' class ranking, grade equivalence, and estimated oral reading fluency (EORF) was acquired from their attended school via the Star Reading national assessment tests (Table 1). The STAR assessment provides norm-reference information regarding reading for grades 1-12. The test analyzes information regarding short comprehension tasks as well as extended comprehension tasks; linking vocabulary to comprehension. The test also provides information regarding the zone of proximal development, which indicates an individualized reading range for the subject. The estimated oral reading fluency (EORF) is equivalent to words per minute that the subject is able to identify accurately and efficiently with optimum comprehension (Renaissance Learning, 2011).

Subject ID	Grade Equivalent	EORF (wpm)	Student Ranking
2	4.6	120	5
7	2.2	58	22
8	2.2	56	23
9	2.5	70	18
10	3.7	103	9
11	6.7	170	1
12	5.7	149	2
14	3.2	86	14
18	3.2	87	13
20	3	81	16
21	4.8	125	4
26	2	51	24
28	2.1	54	23
32	2.3	62	22
35	3.7	102	13
36	0.8	12	25
37	3	81	18
38	5.2	135	2
40	5.1	132	3
42	4.7	123	5
43	4.2	111	11
47	4.2	112	9
48	4.4	114	8

Table 1: Subject and corresponding academic data obtained from the STAR assessment

Subjects who were ranked higher than their classmates in test performance also tended to read words at a faster rate. Visual span size was much larger for EORF rates greater than 120 wpm, with very little difference for visual span sizes corresponding to lower reading rates. It is also noteworthy that the observed variance in visual span size was much smaller for EORF rates greater than 120 wpm as opposed to lower EORF rates. It was also noted that the mean visual span increased with both trigrams and three lettered words as the grade level equivalent (GLE) increased (figure 5). When comparing the visual span size (BITS) of grade school subjects to a similar adult study (Sewell and Raghunandan, 2011) it was found that students performing above the fourth grade level were near the levels of their adult counterparts (figure 5). In addition to these trends, EORF rates and GLE were found to be strongly correlated.

While the mean visual spans for words were larger for higher GLE groups, the variance of word visual spans was quite large across all groups (Figure 5). In addition, the visual span for words were consistently larger than trigrams in all GLE groups. This suggests that the WSE is an active and well-developed process regardless of GLE because it is present even in the lower GLE groups. Figure 5 also shows that visual span for trigrams increase at a much steeper rate with GLE than word visual spans. One possibility for such an effect is that the size of the visual spans reaches maximum at 70.5 BITS (4.7 x 15 letter positions). In GLE groups with larger trigram spans, the effect of the WSE causes the word spans to reach nearly maximum values at a much quicker rate. Additionally, subjects were more accurate at identifying words efficiently, calculated as the ratio of each subjects' visual span in bits divided by the maximum possible visual span for words or trigrams, when compared to trigram recognition. This demonstrates that word superiority is developing at the third and fourth grade levels. The visual spans for trigrams and words seem to increase linearly up to an EORF of 130-140wpm and plateaus thereafter (Figure 6).

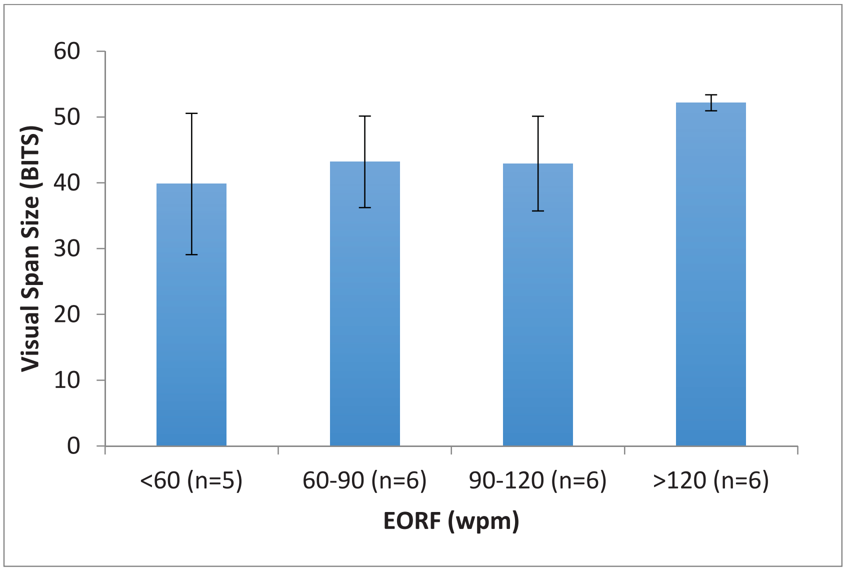

Figure 4: Mean visual span size (+/- 95% CI) for trigrams plotted against Estimated Oral Reading Fluency rate (EORF). Visual span size was calculated as the sum of BITS across 15 letter position (7 to the left and right of fixation, including fixation).

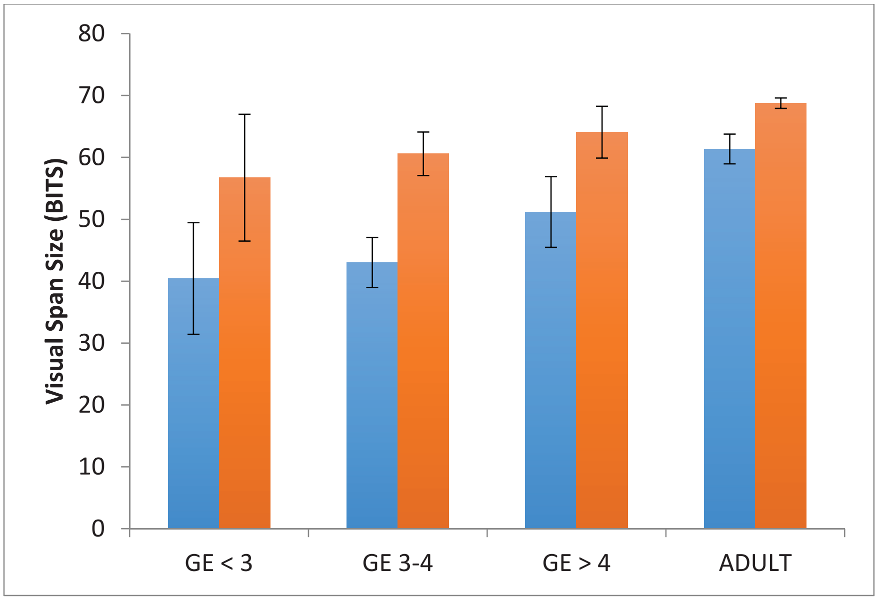

Figure 5: Mean visual span size (+/- 95% CI) for trigrams (blue) and words (orange) plotted against Grade Level Equivalent (GLE). Visual span size was calculated as the sum of BITS across 15 letter positions (7 to the left and right of fixation, including fixation).

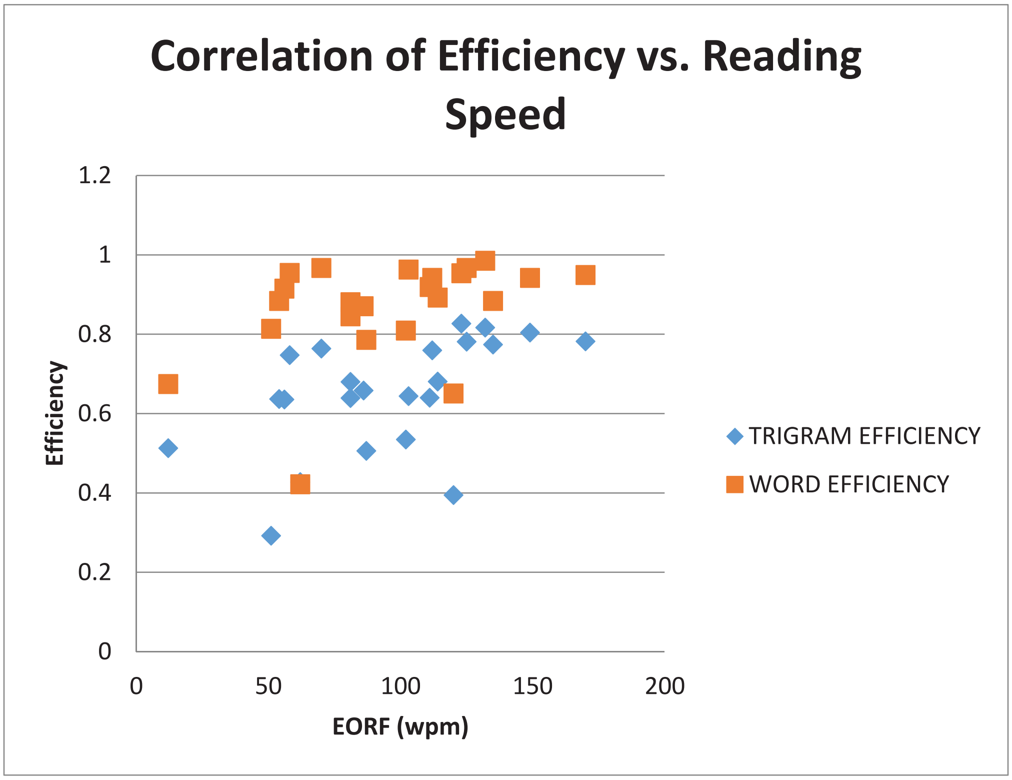

Figure 6: Efficiency of trigrams (blue) and words (orange) plotted against estimated oral reading fluency (EORF). Efficiency was calculated as the ratio of each subject's visual span in bits divided by the maximum possible visual span for words or trigrams

Discussion, Interpretation of Results & Conclusions

The study by Kwon et. al. (2007) showed that the size of visual span increases linearly with increasing grade level and was also significantly correlated with reading speed. The results of the present study are consistent with the preceding report in that subjects who were performing above grade level also had an increased visual span size and reading performance. Legge et. al. (2007) theorized that a smaller visual span may be the sensory bottle-neck that causes slower reading speeds in peripheral vision, and also poses as a low-level limit on reading speed. This inference also seems consistent with the results of the current study in that students with lower reading performance (specifically by GLE) had smaller visual spans.

There appears to be a difference in reading rates among GLE groups even though all GLE groups seem to display compensatory mechanisms that help them to achieve good word recognition performance. Wider trigram visual spans may allow for faster lexical processing because of improved orthographic accuracy. This added perceptual processing load is lower in GLE groups with larger trigram visual spans, which could potentially facilitate their reading speeds. Therefore, the smaller the trigram visual span, the more dependent readers are on the WSE to decipher words, and the longer it takes to arrive at the correct solution.

The main limitations of this study include the very small sample size and the amount of time needed to collect the data. Ideally, all of the testing would have been conducted in a matter of days rather than months to ensure accurate comparisons of each student. A larger sample would also have been helpful to add power to the reported associations. Conducting the study within an optometric clinic would also have provided more accurate/consistent screening results and would have reduced distractions during test administration.

Due to an increased ability to recognize words versus nonwords, the WSE is shown to be developing in the third to fourth grade students sampled in this study; however, few have reached adult-like levels, demonstrating that this is still an on-going process. There does appear to be an association between increased classroom performance and the size of the visual span. Visual span also tended to increase along with grade equivalent, which allows us to infer that perhaps increased visual speed may be associated with superior letter recognition accuracy.

To better understand the full development of the WSE, further testing should be conducted in a larger sample: ideally grades 1-12 for an entire school district. With a larger sample, more correlations could theoretically be made beyond determining the period of development, such as whether or not socioeconomic background has an effect on the length of development or even the quality of word superiority. Other correlations that are recommended for further analysis include if students with dyslexia demonstrate the WSE or not and if students who perform better or worse in various subjects, such as math versus literature, have different levels of word superiority.

Development of the WSE is a necessity to becoming an efficient, fluent reader. Diminished or absent word superiority could have far-reaching consequences on a student both in and out of the classroom. Further understanding this mechanism could potentially aid struggling students to increase their classroom performance.

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Appendices

Appendix 1: IRB Approval form

Ferris State University

Institutional Review Board (FSU - IRB)
Connie Meinholdt, Ph.D. - Chair
820 Campus Drive
Ferris State University
Big Rapids. MI 49307
(231) 591-2759
IRB@ferris.edu

To: Dr. Avesh Raghunandan & Ms. Nina Collins Glauch
From: C. Meinholdt, IRB Chair
Re: IRB Applications #110802 (Title: Developmental change in the Word Superiority and its correlation with Reading Fluency)
Date: November 2nd, 2011

The Ferris State University Institutional Review Board (IRB)* has reviewed your application for using human subjects in the study, "Developmental change in the Word Superiority and its correlation with Reading Fluency" (#110802) and approved it under an *expedited review – 2D*. This approval has an expiration date one year from the date of this letter. As such, you may collect data according to procedures in your application until November 2nd, 2012. However, we ask that in consent documents you replace the term "Human Subjects Review Committee" with "Institutional Review Board" and you may wish to include our e-mail contact (IRB@ferris.edu) in addition to or in place of other committee contact information.

It is your obligation to inform the IRB of any changes in your research protocol that would substantially alter the methods and procedures reviewed and approved by the IRB in this application. Your application has been assigned a project number (#110802) which you may wish to refer to in future applications involving the same research procedure.

Finally, we wish to inform researchers that the IRB now requires follow-up reports for all research protocols as mandated by the Code of Federal Regulations, Title 45 for using human subjects in research. The new follow-up report form is available from the Ferris website (http://www.ferris.edu/htmls/administration/academicaffairs/vpoffice/hsrc/). Thank you for your compliance with these guidelines and best wishes for a successful research endeavor. Please let me know if I can be of future assistance.

**The IRB has been previously called the Human Subjects Research Committee (HSRC)*

Appendix 2: Subject screening data

Subject	OD VA near	OS VA near	Local stereo	Global Stereo	CT near
2	20/30	20/25	20s	positive	4^XP
7	20/15	20/15	50s	positive	ortho
8	20/20	20/20	70s	positive	4^XP
9	20/20	20/15-	100s	positive	2^XP
10	20/20	20/20	50s	positive	ortho
11	20/25	20/25	70s	positive	6^XP
12	20/20	20/20	25s	positive	ortho
14	20/20	20/20	70s	positive	2^XP
18	20/30	20/20	100s	positive	4^XP
20	20/25	20/20	50s	positive	2^XP
21	20/20	20/15-	50s	positive	4^XP
26	20/20-	20/20	200s	positive	2^XP
28	20/15	20/20-1	100s	positive	2^XP
32	20/20+	20/20	20s	positive	4^XP
35	20/15-3	20/15-2	200s	positive	ortho
36	20/25-	20/20+	40s	positive	4^XP
37	20/15-	20/15-	70s	positive	ortho
38	20/25-2	20/25-3	200s	positive	1^XP
40	20/30-2	20/20	30s	negative	6^EP
42	20/20-2	20/15	20s	positive	2^EP
43	20/15-	20/15-	140s	positive	1^XP
47	20/20	20/20	100s	positive	ortho
48	20/20	20/20-	70s	positive	2^XP