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INTERACTION BETWEEN MEMORY DECAY, VISUAL SPAN, AND THE SIZE OF LETTER STRING

We, Berta Karmazinaite and Taisiya Dulin, hereby release this Paper as described above to Ferris State University with the understanding that it will be accessible to the general public. This release is required under the provisions of the Federal Privacy Act.

[redacted]

Doctor of Optometry Candidates

05/02/2017

Date

INTERACTION BETWEEN MEMORY DECAY, VISUAL SPAN, AND THE SIZE OF THE LETTER STRING

by

Berta Karmazinaite

Taisiya Dulin

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, 2016

INTERACTION BETWEEN MEMORY DECAY, VISUAL SPAN, AND THE SIZE OF LETTER STRING

by

Berta Karmazinaite

& Taisiya Dulin

Has been approved

1 May, 2017

APPROVED: [redacted]

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ACCEPTED: [redacted]

Faculty Course Supervisor

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ABSTRACT

Background: It is believed, there are significant interactions between letter recognition accuracy and string length (which in turn depends on the serial position of the letter within the string) due to combined limitations presented by both memory load and memory decay. The goal of this study is to investigate the visual span shrinkage due to memory load and decay with increasing letter string length. *Methods*: Ten adult subjects were used in this study to measure letter recognition accuracy with random 3-letter trigrams and 5-letter pentagrams on a computer screen at varying letter positions to the left and right of fixation. Subjects were asked to report all 3 or all 5 letters in complete report and single letter in partial report. Letters were black lowercase Courier with contrast appearing for 100 milliseconds. *Results:* Results will be aimed to three specific goals: 1) To quantify the effects of report condition on letter recognition accuracy for two string length conditions; 2) To investigate the effect of report condition on letter recognition accuracy as a function of the serial position of a character within trigrams and pentagrams; 3) To investigate the effect of report condition on letter sequence recognition accuracy as a function of character's inner and outer position within the trigram and pentagram. *Conclusions:* Visual span decreased significantly with increasing strings length. Higher cortical processes such as memory load and decay as well as crowding effects play an important role in the ever-changing visual span.

ACKNOWLEDGMENTS

We thank Dr. Avesh Raghunandan for providing the insight and expertise that greatly assisted this research. We thank you for sharing your pearls of wisdom and supporting us through this research.

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CHAPTER 1

INTRODUCTION

Reading is a learned behavior that involves complex interactions between low level and high level perceptual processes. The visual basis of reading involves the intake of visual symbols that are ultimately decoded into language[1]. In other words, visual-based reading is associated with letter discrimination which is then decoded into a meaningful word. This process is known as the grapheme-to-phoneme decoding. Hence this learned behavior encompasses complex interactions between low level factors such as visual acuity, crowding, and eye movement control, and high level factors such as, vocabulary, context, past experiences, and visual attention[2-6]. While the above examples are not exhaustive, it does show the complexity of the reading process, and highlights the various areas of vulnerability in developing an efficient reading strategy.

Several reports proposed that the visual span is a fundamental low level limit on reading[2,3] . The visual span is defined as the number of letters that can be discriminated at and on either side of fixation without the execution of an eye movement[2,3,4]. Essentially, the hypothesis posed by Legge was that shrinkage in the size of the visual span is associated with decrease in reading speed, possibly due to the need for more frequent fixations and saccadic eye movements[2,3,4] (specifically for paragraph reading). Furthermore, developmental changes in the visual span also seem to parallel same changes in reading speed[5]. These results cumulatively suggest that reading speed is intimately associated with the visual span, and the visual span is an important factor acting as a sensory bottleneck for visual information available to higher level processes. In other words, the larger the visual span, the more information can get to higher level processes to be decoded into meaningful words per fixation duration.

Previous studies have used trigrams, which are letter strings containing three contiguous letters, as the basis for studying visual span. However, given that conventional reading text employs words of varying string lengths, it is unknown how increasing string length will impact visual span measures. Letter recognition accuracy is known to decrease as string length is increased, and reading rate also decreases as word length increases[4]. These observations show the close interaction between word length and visual span, and the potential interaction between visual span and reading speed. In addition, it is known that memory load affects recall accuracy as a function of time due to memory decay following the presentation of the stimulus[6]. Short term memory plays an important role as well due to its limited capacity to store visual information. Another important factor in report accuracy is the serial position of a letter asked to be recalled within the string which may impose crowding effects and decrease recall accuracy[7]. Therefore, the aim of this study is to investigate the effects of memory load, memory decay, and crowding effects on letter recognition accuracy, specifically as it relates to the visual span size measured with trigrams (3 letter string) and pentagrams (5 letter string).

The results of the study suggest that the visual span size is a dynamic property that varies significantly with letter string length. Furthermore, crowding effects have a strong impact on recall accuracy that also varies considerably with letter string length. It has been reported in previous studies that crowding and memory decay affect recall accuracy and in this study, it is evident that these limiting factors have stronger effect with increasing string length. Furthermore, memory decay portrays an increasingly prominent effect on recall accuracy in eccentricity. Additionally, pentagrams illustrate a significant decrease in letter recognition accuracy for letter positions containing least crowding effect suggesting that there may be another limiting factor at play.

CHAPTER 2

METHODS

The study comprised ten volunteer subjects who were required to meet specific criteria. All ten subjects were graduate-level optometry students between ages 23 and 28. The following requirements had to be met in order to qualify to participate in the study.

- Near visual acuity of 20/25 (logMAR -0.1) or better OD, OS, and OU
- Heterophoria between 2 p.d. of esophoria and 8 p.d. of exophoria and no heterotropia. Measured with cover test at 50cm.
- Local stereopsis of 40 arc sec or better and at 250" of random dot stereopsis or better. Measured with Wirt Rings and Randot StereoTest.
- Denying past or existing reading, learning, developmental abnormalities or delays.
- Passing sub-tests 1-5 of the Woodcock Johnson – WJ III Diagnostic Reading Battery test using the following criteria.

➢ Perform above 12 grade level equivalent on the following diagnostic reading tests from the WJ III Diagnostic Reading Battery. Those included letter-word identification, word attack, reading vocabulary, passage comprehension, and reading fluency.

SUBJECTS	1	2	3	4	5	6	7	8	9	10
VA (3m) OD	-0.18	-0.06	-0.08	-0.02	-0.1	-0.18	-0.08	-0.04	-0.06	-0.04
OS	-0.18	-0.06	-0.08	-0.08	-0.16	-0.18	-0.08	-0.18	-0.04	-0.04
OU	-0.2	-0.1	-0.1	-0.16	-0.16	-0.18	-0.1	-0.12	-0.18	-0.06
VA (40cm)	0	-0.08	-0.1	-0.1	-0.08	-0.08	-0.08	-0.1	-0.1	-0.2
OD	0	-0.1	-0.1	-0.1	0	-0.1	-0.1	-0.1	-0.1	-0.2
OS OU	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.2
Cover Test 3m	1^XP	1^XP	3^XP	Ortho	Ortho	Ortho	2^XP	Ortho	4^XP 0.5^L hyper	4^XP
40cm	Ortho	Ortho	6^XP	2^EP	2^XP	6^XP	Ortho 0.5^R hyper	2^XP 0.5^R hyper	4^XP 0.5^L hyper	4^XP
Stereopsis	20	20	20	40	20	40	20	20	20	30
Wirt Rings Random Dot	250	250	250	250	250	250	250	250	250	250
WJ III DRB	>18.0	>18.0	>18.0	>18.0	>18.0	>18.0	>18.0	>18.0	16.8	>18.0
Test 1	>18.0	>18.0	>18.0	>18.0	>18.0	13	12.4	13.0	>18.0	>18.0
Test 2	>18.0	12.9	>18.0	15.5	12.9	>18.0	12.9	15.5	>18.0	12.9
Test 2	13.7	>18.0	>18.0	>18.0	16.3	13.2	14.2	14.8	>18.0	>18.0
Test 5 Test 5	13.3	>18.0	>18.0	>18.0	>18.0	>18.0	12.6	>18.0	12.6	>18.0

Table 1: Pre-screening results of the 10 subjects used in the study. For Visual Acuity (VA) at 3 meters and 40 centimeters, OD indicates right eye, OS indicates left eye, and OU indicates both eyes. The visual acuity was recorded in logMAR. Cover test recorded in prism diopters with XP for exophoria, EP for esophoria, ortho for orthophoria, and R or L hyper for right or left hyperphoria. Stereopsis is recorded in seconds of arc and WJ III DRB sub-tests include Letter word identification (test 1), passage comprehension (test 2), word attack (test 3), reading vocabulary (test 4) and reading fluency (test 5). The results of the five sub-tests indicate the grade level equivalent.

Letter recognition accuracy was measured using random three letter trigrams and five letter pentagrams presented on a Dell Trinitron CRT monitor with 120 Hz refresh rate. The letters used were all black lowercase Courier font set at 0.84 high contrast with a white background and subtended 0.4 degrees total vertical extent at the fixation distance. The spacing between the letters was set at 1.16X of the height of lowercase “x” (equivalent to the standard inter-letter spacing used in Courier font). The stimulus was presented for 100ms in all conditions, with temporal duration calibrated using a photodetector and a Tektronix oscilloscope. Subjects were set at 0.57 m fixation distance from the monitor

-8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 Position of each letter Relative to fixation

f m p Example of a trigram

▪

1 2 3 Serial position of letters

Figure 1: Stimulus set-up illustration. "fmp" is the stimulus which in this case is a trigram. Five letter stimulus would be a pentagram. Numbers above the stimulus indicates letter position occupied by each letter comprising the stimulus relative to fixation, The value of 0 corresponds to the fixation, -1 through -8 corresponds to stimulus appearing to the left of fixation and 1-8 would be to the right of fixation. Numbers 1, 2, and 3 at bottom indicate the letter's serial position within the trigram. In case of a pentagram, each letter's serial position would be 1 through 5.

PROCEDURE: Prior to the presentation of each string sequence, subjects fixated between a pair of 6 arc minute fixation squares separated vertically by a space of 72 arc minutes. In the case of the trigrams, the 3-letter string was randomly presented within 3 contiguous letter positions of 17 available positions tested. As an example, if the trigram "fmp" was centered at letter position 0 (Figure 1), then the center letter "m" of the trigram occupied the "0" position, the letter on the left ("f") occupied letter position"-1" and the letter to the right ("p") occupied letter position. Even though 17 letter positions were available (-8 to +8), only 13 letter positions (-6 through +6) were used in the analysis because it was only in these letter positions that the first, second and third letter of the trigram could be presented (furthermore, these letter positions were chosen to match those with pentagrams). Therefore each trigram was presented with either its first, second or third letter occupying each of 13 letter positions. In the case of the pentagrams, each string comprised random 5-leter sequences. The pentagram strings were presented at the same letter positions relative to fixation as outlined for the trigrams. Even though 21 letter positions were available (-10 to +10), only 13 letter positions (-6 through +6) were used in the analysis because it was only in these letter positions that the first, second, third, fourth, and fifth letter of the pentagram could be presented. For any given letter position, a single block of trials comprised 15 repetitions when that letter position was occupied by the first through third letter of a trigram sequence or first to fifth letter of the pentagram sequence.

The stimulus was presented for duration of 100ms to prevent saccadic eye movements. The subject reported the letters by typing them on a key board. For partial recall procedures, the subject was informed as to which serial position of the stimulus they are to report prior to the start of the procedure. For analysis of trigrams, four separate procedures were conducted. Subject was asked to report either the 1st serial position of the trigram, the 2nd, or the 3rd (Partial Report), or to report all 3 letters of the trigram (Complete Report). For analysis of pentagrams, six separate procedures were performed. Subject was asked to report either the 1st, 2nd, 3rd, 4th, or 5th serial position of the pentagram (Partial Report), or all five letters of the pentagram (Complete Report). Each letter recalled correctly was given a score of “1” while incorrect reports were given a score of “0”. The scores were then added up for each serial position of trigrams and pentagrams.

To assess the effect of report condition on the overall area of the letter recognition profiles depicted in Figure 1B, the proportion correct for the left letter positions (-6 to 0) and right letter positions (0 to +6) for each subject's data were fit separately with a best-fit Gaussian function by minimizing the sum of the squared errors. The total area (A_T) under each fitted function was then computed as follows:

$$A_T(x) = \left[\int_{-6}^{0} P_{max\ left} * \exp\left(\frac{(-x_L)^2}{2*\sigma_L{}^2}\right)\right] + \left[\int_{0}^{6} P_{max\ right} * \exp\left(\frac{(-x_R)^2}{2*\sigma_R{}^2}\right)\right]$$

$P_{max\ left}$ = Peak amplitude for left fit

$P_{max\ right}$ = Peak amplitude for right fit

σ_L = standard deviation for left fit

σ_R = standard deviation for right fit

x_L = left letter positions (-6 to 0)

x_R = right letter positions (0 to +6)

CHAPTER 3

RESULTS

Letter Recognition accuracy for Trigrams and Pentagrams:

Proportion of correct letter recognition was taken as a measure of letter recognition accuracy. Letter recognition accuracy (+/- 95% CI) for both trigrams and pentagrams or each report condition is plotted in Figure 2 for 13 letter positions relative to fixation (-6 to +6) pooled across 10 subjects. Each datum in Figure 2 represents the cumulative proportion (+/- 95% CI) for all 3 letters of a trigram and all 5 letters of a pentagram presented at each letter position relative to fixation. Therefore, the proportion of correct responses was derived from a total of 45 (15x3) presentations for trigrams and 75 (15x5) presentations for pentagrams for each subject.

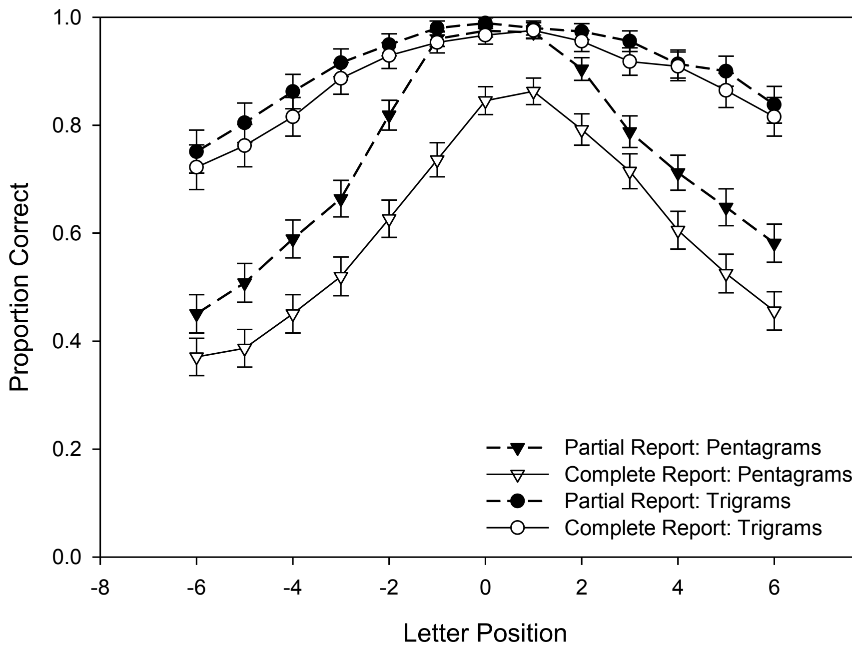

Figure 2: Letter recognition accuracy (+/- 95% CI) plotted as a function of letter position relative to fixation for trigrams (circles) and pentagrams (triangles). The complete report condition is represented as unfilled symbols, while the partial report condition is presented as filled symbols.

A Mann Whitney Rank sum test on the raw scores of 10 subjects across 13 letter positions indicated a significant effect of report condition (Median Partial Report = 42, Median Complete Report = 41, U = 7084.5, $p = 0.024$). Similarly, there was a significant effect of report condition for pentagrams (Median Partial report = 54, Median Complete Report = 43.5, U = 5236.5, $p < 0.001$). A Kruskal-Wallis One Way ANOVA on the raw scores of 10 subjects also showed a significant effect of letter position in trigrams (Partial Report: H = 97.625, df = 12, $p < 0.001$; Complete

Report: H = 80.068, df = 12, p < 0.001) and pentagrams (Partial Report: H = 117.215, df = 12, p < 0.001; Complete Report: H = 112.864, df = 12, p < 0.001).

Serial position and the effect of report condition:

In an attempt to analyze the effect of report condition on letter recognition accuracy for each serial position of the trigram and pentagram, Gaussian functions were fit to the letter recognition profiles for each serial position and report condition to calculate the area under the best fit function using the method described earlier. Figures 2D and 3F plots the mean total area (+/- 95% CI) for each serial position of a letter within the trigram and pentagram separated according to report condition, respectively.

Consistent with previous report[3], letter recognition accuracy was lower for the middle serial positions regardless of string length and report condition compared to the initial and final letter positions within each string length condition, i.e. serial position 2 for trigrams (Figure 2D) and serial positions 2, 3, and 4 for pentagrams (Figure 3F) (Two Factor repeated measures ANOVA (Serial position x Report condition) using the Holm-Sidak Multiple comparison method: Trigrams: 1^{st} letter vs 2^{nd} letter (t = 8.9, p < 0.001), 3^{rd} letter vs 2^{nd} letter (t = 5.158, p < 0.001)) , Pentagrams: 1^{st} letter vs. 2^{nd} letter (t = 16.717, p <0.001), 3^{rd} letter (t = 26.578, p <0.001) and 4^{th} letter (t = 24.085, p <0.001), and the 5^{th} letter vs. 2^{nd} letter (t = 4.592, p <0.001), 3^{rd} letter (t = 14.453, p <0.001) and 4^{th} letter (t = 11.960, p <0.001)).

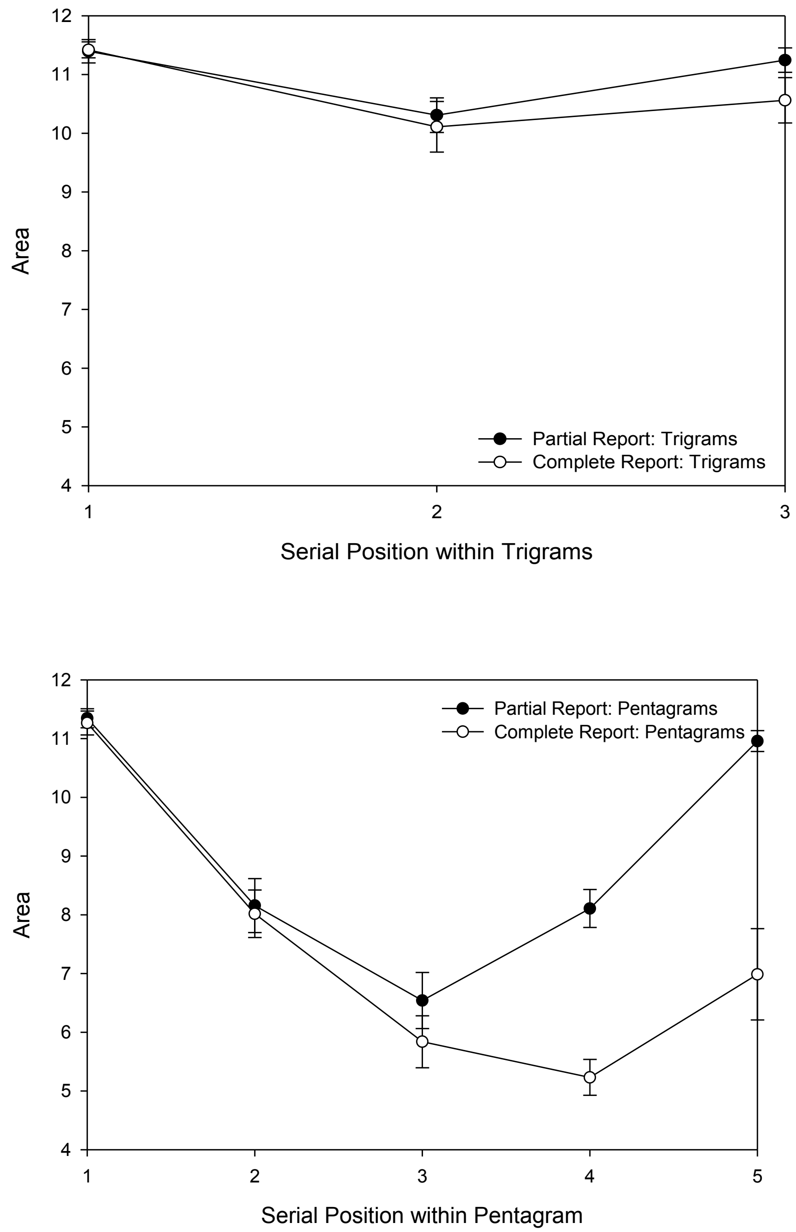

Figure 3: Mean area (+/- 95% CI) of letter recognition profiles when parsed according to the serial position of the letter comprising a trigram (top graph) or a pentagram (bottom graph).

Furthermore, recognition accuracy of the 1st and 2nd letters in trigrams (Figure 3A) and pentagrams (Figure 3B) was unaffected by report condition regardless of the hemi-field in which they were presented (Two Factor repeated measures ANOVA (Serial position x Report condition) using the Holm-Sidak Multiple comparison method (Complete vs. Partial Report): Trigram: 1st letter ($t = 0.153$, $p = 0.879$), 2nd letter ($t = 1.306$, $p = 0.203$) ; Pentagram: 1st letter ($t = 0.300$, $p = 0.765$), 2nd letter ($t = 0.519$, $p = 0.606$) . Partial report had the most consistent effect on the 3rd letter position in trigrams ($t = 4.488$, $p < 0.001$) and the 3rd ($t = 2.614$, $p = 0.012$), 4th ($t = 10.692$, $p < 0.001$) and 5th ($t = 14.770$, $p <0.001$) letter in pentagrams.

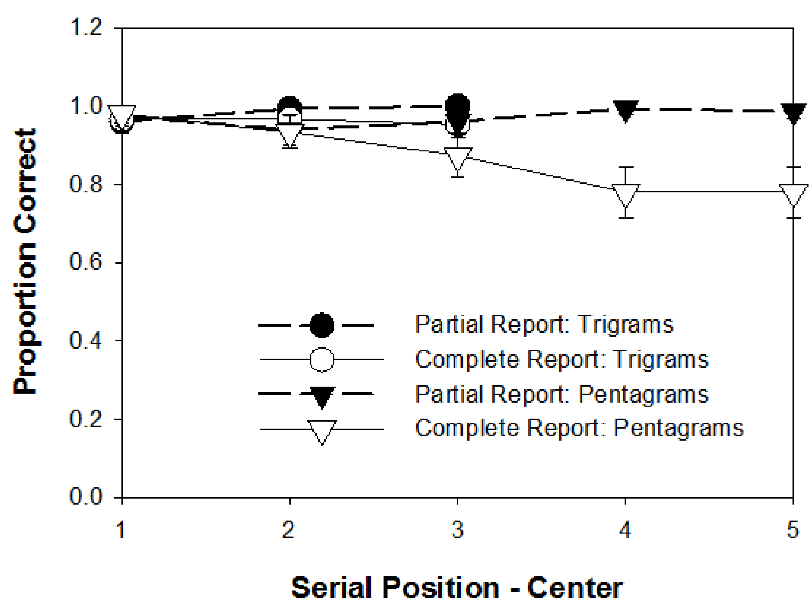

Figure 4: Letter recognition accuracy (+/- 95% CI) is plotted as a function of the serial position of letters comprising trigrams (circles) and pentagrams (triangles) when centered on letter position 0.

The 3rd serial position in trigrams contributed to about 77% of the increase in total area with partial report, whereas the 4th and 5th letters within pentagrams cumulatively accounted for approximately 88% of the increase in total area with partial report.

An additional observation that can be gleaned from inspection of Figure 4 is that for the “0” abscissa value (central fixation), letter recognition accuracy for all 3 serial positions in trigrams is close to perfect performance for the complete report procedure, however, in the case of pentagrams, there was a systematic decrease in letter recognition accuracy from serial positions 1 to 5 (specifically for serial positions 3 to 5). The limitations imposed by acuity and positional uncertainty are deemed negligible at foveal fixation and are therefore unlikely contributors to any observed decreases in letter recognition accuracy at fixation. Furthermore, it is also arguable that foveal crowding/ masking at fixation is also of small magnitude in this case given the almost perfect performance with trigrams presented at fixation, and the perfect performance of pentagrams presented at fixation observed with the partial report condition. Therefore, the authors propose that the result observed with pentagrams is a manifestation of the combined limitations imposed by memory load and decay which are significant for centrally presented pentagrams, but negligible for centrally presented trigrams. Furthermore, it also appears that memory (load and decay) seem to exert an increasingly adverse effect on letter recognition with increasing eccentricity relative to fixation. This observation also seems true for trigrams, specifically in the left hemi-field.

Summary of results:

1. Report condition affects letter recognition accuracy for both string length conditions. Partial report improved letter recognition accuracy compared to complete report.
2. Letter recognition accuracy is lowest for letters occupying middle serial positions within a trigram or pentagram. This effect becomes more pronounced with increasing viewing eccentricity, an observation which is consistent with the predictions of visual crowding.
3. The effect of report condition is most significant on the letter recognition occupying latter serial positions regardless of string length and viewing eccentricity. This effect is larger for the longer string length.
4. The results of 3 are not consistent with the predictions of visual crowding, acuity limitations or position uncertainty, but rather provide evidence for the influence of visual memory factors (load and decay) as contributors to this result.

CHAPTER 4

DISCUSSION

This study set out to investigate the effects of report condition on letter recognition accuracy with trigrams (3 letter string) and pentagrams (5 letter string). The main results of this study can be summarized as follows:

1. Report condition affects letter recognition accuracy for both string length conditions. Partial report improved letter recognition accuracy compared to complete report.
2. Letter recognition accuracy is lowest for letters occupying middle serial positions within a trigram or pentagram. This effect becomes more pronounced with increasing viewing eccentricity, an observation that is consistent with the predictions of visual crowding.
3. The effect of report condition is most significant on the letter recognition occupying letter serial positions regardless of string length and viewing eccentricity. This effect is larger for the longer string length.

The first result is the novel finding reported in this study and has important implications on the current understanding of letter recognition accuracy. The span of letter recognition accuracy (which forms the fundamental basis of visual span measures) represents a low-level bottleneck for higher levels of reading processing[4]. These low-level visual limitations include acuity limitations, visual crowding and positional uncertainty. In this study, font size was chosen to exceed acuity threshold even at the most eccentricity letter positions. The effect of visual crowding and positional uncertainty between the two report conditions should remain invariant, because the stimulus properties and presentation duration were the same for the two report conditions. Therefore, the difference in performance between these two report conditions must represent the involvement of higher-level factors. The authors speculate that the involvement of higher-level visual memory factors (such as load and decay) presents as the most plausible candidate to account for the difference in letter recognition between the two report conditions.

Evidence in favor of this theory is summarized in point 3 above and is built upon in the following paragraph. The improvement in letter recognition accuracy with partial report was confined to the letter serial positions of trigrams and pentagrams regardless of the letter position in which they were presented. Firstly, observations that letter recognition accuracy improved with partial report for the 3rd, 4th, and 5th serial positions when pentagrams were centered at letter position 0, and not for trigrams (i.e serial position 3), is consistent with a visual memory capacity limitation. At these letter positions relative to fixation, positional uncertainty and arguably visual crowding are minimal. Furthermore, the lack of an effect noted with trigrams at that location is consistent with previous reports that visual memory seems to have a capacity limitation of about 4 elements[8]. This capacity limitation can also vary depending on the cognitive complexities of the elements that are required to be recalled/reported[9]. In this case, cognitive complexity should remain comparable between string lengths as the sample of letters used were the same in both string length conditions.

Secondly, the effect of the partial report condition on the letter serial positions increased significantly with increasing viewing eccentricities relative to fixation. This effect was noted for the trigrams and pentagrams. Consequently, if visual memory capacity limitations were solely responsible for the increase noted with partial report, then the magnitude of the improvement noted with partial report should not vary significantly with increasing viewing eccentricity. Furthermore, trigrams should also remain immune to report condition for the reason outlined in the previous paragraph. The authors propose an additional factor to account for this observation. It is conceivable that crowded targets are subject to delays in perceptual processing and memory encoding. This cumulative delay could impose further delays in memory encoding of serial positions following crowded letters elements within a trigram (serial position 2) or pentagrams (serial position 2,3 and 4). Therefore, with partial report, it is conceivable that report of the cued target letter is minimally affected by the processing preceding target elements, hence the improvement noted in report accuracy. We have shown subsequently, in a separate study, that crowded targets are indeed associated with slower processing speeds (inferred from response time dynamics). Furthermore, the processing speed varies inversely with the recognition accuracy of crowded targets. Current studies are being conducted to elucidate the interactions between crowded and uncrowded targets on visual memory encoding and decay.

In summary, the current study provides convincing evidence that letter recognition accuracy (and its associated visual span) are affected significantly by higher-level visual memory factors (in addition to crowding, positional uncertainty and visual acuity). This effect is exaggerated with viewing eccentricity and with increasing string length. The study provides evidence which alludes to visual crowding introducing perceptual processing delays in letter recognition accuracy which may also exert an adverse effect on the memory trace of letter elements located in serial positions following a crowded target.

CHAPTER 5

CONCLUSION

The current study provides convincing evidence that letter recognition accuracy depends on low-level and higher-level visual limitation factors. Low-level visual limitations include acuity limitations, visual crowding and positional uncertainty. Higher-level visual memory factors are load capacity and memory decay. Taking above statements into consideration, this study concludes the following:

- Letter recognition accuracy is superior with partial report compared to complete report. This is consistent with the predictions of visual crowding, acuity limitations, position uncertainty, in addition to load and memory decay.
- Letter recognition accuracy is lowest for letters occupying middle serial positions within a trigram or pentagram. This effect becomes more pronounced with increasing viewing eccentricity, an observation which is consistent with the low-level visual limitations.
- The effect of report condition is most significant on the letter recognition occupying letter serial positions regardless of string length and viewing eccentricity. This effect is larger for the longer string length, an

observation which is consistent with the higher-level visual memory factors.

This study also concludes that letter recognition processing speed varies inversely with the recognition accuracy of crowded targets. The crowded targets are subjected to delays in perceptual processing and memory encoding, and associated with slower processing speeds. Current studies are being conducted to elucidate the interactions between crowded and uncrowded targets on visual memory encoding and decay.

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APPENDIX A

IRB APPROVAL FORM

FERRIS STATE UNIVERSITY

Institutional Review Board for Human Subjects in Research
Office of Research & Sponsored Programs, 220 Ferris Drive, PHR 308 · Big Rapids, MI 49307

Date: May 18, 2016

To: Dr. Avesh Raghunandan

From: Dr. Gregory Wellman, IRB Chair
Re: IRB Application #150504 *(Processing speed differences of word discrimination between central and peripheral retinal regions)*

The Ferris State University Institutional Review Board (IRB) has reviewed and approved your request for an extension to continue using human subjects in the study, *"Processing speed differences of word discrimination between central and peripheral retinal regions"* (#150504). This approval has an expiration date of one year from the date of this letter. **As such, you may collect data according to the procedures outlined until May 18, 2017.**

Your project will continue to be subject to the research protocols as mandated by Title 45 Code of Federal Regulations, Part 46 (45 CFR 46) for using human subjects in research. 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 your application. Thank you for your compliance with these guidelines and best wishes for a successful research endeavor. Please let us know if the IRB can be of any future assistance.

Regards,

Ferris State University Institutional Review Board

Office of Research and Sponsored Programs