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Variation of Responses Times to Letter Strings with Increasing Viewing Eccentricity

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VARIATION OF RESPONSE TIMES TO LETTER STRINGS WITH INCREASING VIEWING ECCENTRICITY

by

Nathan Charles Traxler

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by

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____ May, 2018

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VARIATION OF RESPONSE TIMES TO LETTER STRINGS WITH INCREASING VIEWING ECCENTRICITY

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ABSTRACT

Background: Some individuals with severe central scotomas employ eccentric viewing for reading but at a slower rate compared to normal foveal fixation, despite utilizing adequate magnification. It is conceivable both pre-lexical and lexical processing delays may contribute to reduced reading speeds with increasing viewing eccentricity. Therefore, the purpose of this experiment is to measure the response times (inferred as processing speed) and recognition accuracy of random letter strings with increasing viewing eccentricity to explore pre-lexical processing delay trends. *Methods:* Letter recognition accuracy and keyed-entry response times were measured for trigrams and pentagrams in 5 adult subjects under partial reporting conditions in which a single pre-cued letter within a letter string was reported. Letters were presented for 100ms, rendered in high contrast (0.8), utilizing black lowercase Courier font, at a fixation distance of 57cm. *Results:* Under partial reporting conditions, response accuracy and response times depended on string length, serial position of a letter within a string and viewing eccentricity. In trigrams and pentagrams, a trend of increasing response times as response accuracy decreased was observed. Additionally, when response accuracy was high (for example at fixation) response times were higher when flanked by more targets. *Conclusions:* The results suggests that crowded targets are not only associated with decreased recognition accuracy but also delayed perceptual processing as inferred from longer measured response times. This interaction increases with viewing eccentricity. Additionally flanking targets impose additional processing delays even when recognition accuracy is affected minimally.

TABLE OF CONTENTS

LIST OF FIGURES

All error bars found on all tables represent 95% confidence intervals

VARIATION OF RESPONSE TIMES TO LETTER STRINGS WITH INCREASING VIEWING ECCENTRICITY

INTRODUCTION

Vision loss and blindness is a worldwide concern. While much of the world population's blindness is due to lack of refractive care, ocular diseases are also prominent throughout much of the world. Unfortunately, many ocular diseases have a severe impact on central visual function exclusively. One of these ocular diseases that decreases central retinal function is age-related macular degeneration. In 2016 11 million people in the United States had some form of age-related macular degeneration and the number is potentially doubling to nearly 22 million by 2050. On a worldwide scale, the number of people with macular degeneration is expected to reach 196 million by 2020 and later by 2040 increase to 288 million[1]. Often in individuals with advanced macular degeneration, the peripheral retina is left intact and with normal function. Individuals with severe central vision loss may employ the technique of "eccentric viewing" to maximize visual function. This technique puts emphasis on the utilization of peripheral retina for visual tasks that normally the central retina would be responsible for processing.

One of these common aforementioned visual tasks is reading. Reading is the most common visual complaint for AMD patients who undertake low vision training[2]. It has been documented that reading speeds decrease in eccentric viewing conditions despite adequate magnification[3]. It also has been suggested there is an increase in the magnitude of crowding interactions along with a narrowing of the visual span in peripheral reading techniques which account for the reduction of reading speeds[4,5]. However, is conceivable that crowded letter targets may impose additional processing delays on letter information acquisition at a prelexical level (i.e. prior to giving meaning to letter strings), therefore also contributing to slower reading speeds in the peripheral retina. This study had two objectives to investigate. First to compare response time and accuracy of letter recognition at varying degrees of eccentricity. Response times to letter recognition was taken as an indirect estimate of perceptual processing time. The second objective was to determine if there was an inverse relationship between response accuracy and response times of letter recognition.

METHODS

With utilization of the program writing software Matlab©, random letter strings were presented under controlled conditions to five adult graduate students. These subjects all possessed at least .04 LogMAR acuity OD and OS at distance and near (40cm) and at least 30” of contour stereopsis and 250” of random dot stereopsis. Letter strings were generated at random from a sample of all 26 letters comprising the English alphabet and presented as 3 contiguous letters (trigrams) or 5 contiguous letters (pentagrams). Subject responses were entered and recorded by the subjects via keyboard. Subjects were instructed to report responses under a partial recall condition. In partial report conditions only a single pre-determined letter position within the string was asked to be recalled. The letter strings were presented for 100 milliseconds to prevent reflexive saccadic eye movements that would allow foveal fixation after 200 milliseconds of viewing[6].

Letter characters were rendered in high contrast (.8), in lowercased, standard-boldness Courier font, and presented at a fixation distance of 57cm. Letter strings were presented in 13 serial positions that varied in eccentricity (-6 representing the most left position, 0 being at fixation, and 6 being the most right position). Standard inter-letter spacing was used which corresponded to ~1.16x width of a lowercase case letter. During each testing cycle 15 measurements were taken at for each serial position within a trigram or pentagram and for each of 13 letter positions. Recording of the response times and accuracy of the response was completed within the Matlab© program. Results were later generated and analyzed using Microsoft Excel© spreadsheets.

RESULTS

Figures 1 and 2 are respective plots of the average response accuracy for each serial position within trigrams and pentagrams respectively for each letter position relative to fixation (represented as positions -6 through +6). Regardless of serial position, response accuracy was highest at fixation (Two way ANOVA (Letter position x Serial Position): Letter position $F(12,38) = 2.27$, $p = 0.042$), Serial position $F(2,38) = 5.03$, $p = 0.015$) . However, as viewing eccentricity increased, response accuracy depended upon the serial position and the hemi field of its presentation. Outer letters (i.e. letters in serial position 1 of trigrams and pentagrams) exhibited higher response accuracies in the left hemifield but lower response accuracy in the right hemifield. The opposite was true for the inner letters (i.e. letters in serial position 3 of trigrams and 5 of pentagrams). Middle letters (serial position 2 of trigrams and 2, 3, 4 of pentagrams) were reduced in both hemifields, however, response accuracy in general was usually higher in the right hemifield.

Figures 3 and 4 are respective plots of response times for each serial letter position for trigrams and pentagrams for each letter position relative to fixation (again represented as positions -6 through +6). The change in response times depended on viewing eccentricity and serial position of the letter within each string length. In the case of the trigram partial report condition, there were significant main effects of serial position ($F(2,194) = 5.456$, $p = 0.032$), a significant main effect of letter position relative to fixation ($F(12,194) = 6.087$, $p < 0.001$), however, the interaction between serial position and letter position relative to fixation was not statistically significant ($F(24,194) = 1.372$, $p = 0.142$). Much of the main effect noted with letter position relative to fixation could be attributed to the longer response times associated with letter position +6 and -6 in serial position 2 and letter position - 6 in serial position 3, compared to central letter positions. In the case of the pentagram partial report condition, there were significant main effects of serial position ($F(4,324) = 30.473$, $p < 0.001$), letter position relative to fixation ($F(12,324) = 11.340$, $p < 0.001$), and a significant interaction between serial position and letter position relative to fixation ($F(48,324) = 3.487$, $p < 0.001$). Response times increased progressively as letter position increased to the left and right of fixation specifically for serial positions 2, 3, and 4, but not for serial positions 1 and 5. In summary, the partial report response time data suggests that crowded letter elements (2 in trigrams, and 2, 3, 4 in pentagrams) are associated with longer response times which tend to increase progressively with increasing viewing eccentricity.

Figures 5 and 6 compare the average proportion correct of responses against average response times (+/- 1SEM) in all individual pre-cued letter positions in partial recall conditions for trigrams and pentagrams respectively. In summary, figures 5 and 6 illustrate a trend of decreasing response accuracy as response time generally was on average increased, indirectly representing a pre-lexical letter processing delay as this author suggests.

DISCUSSION

As previously mentioned, this research paper was undertaken with two objectives, first, to compare response time and accuracy of letter recognition in varying degrees of eccentricity, and second, to determine the presence of a relationship between response accuracy and response times of letter recognition. For trigrams and pentagrams, a higher proportion correct of responses were obtained in the right eccentric viewing conditions when compared to left eccentric viewing conditions, and is consistent with previous reports [4,9]. The author speculates this is a result potentially caused by all subjects being English language speakers who traditionally read letter information from left to right. Additionally other research implies the function and ability of the peripheral visual fields ability to discriminate visual information accurately and quickly can trained and increased depending on visual experience and functional demands of vision[7].

The findings of this study also appear to demonstrate an inverse relationship between response times and report accuracy. This relationship is apparent in both trigram and pentagram partial recall conditions (Figures 5 and 6). As response accuracy decreases there is clear evidence of an increase in response times. This result suggests that, especially in the case of letters occupying the middle serial position, as crowding increases, response times also increases. This finding appears in support of the hypothesis that crowded targets are associated with longer processing times as inferred from response time measures.

It is also observed that more left letter serial positions within trigrams and pentagrams (aka. Outer letters) on average had higher response times and lower proportion accuracies of response in more eccentric viewing conditions to the right of fixation. However more right serial letter positions (aka inner letters) within trigrams and pentagrams more eccentric viewing conditions to the right of fixation had higher response times and lower proportion accuracies of response on average. This inner/outer anisotropy in report accuracy (Figures 7 and 8) is consistent with previous reports of an inner/ outer anisotropy observed with crowding as well[8]. These two trends suggest that crowding and not viewing eccentricity per se, is associated with longer response times, which adds further impetus to the suggestion that crowded targets may be associated with longer pre-lexical processing delays compared to un-crowded targets. This discovered trend would likely serve as a basis for further investigation.

An additional observation from these results (Figures 7 and 8) show that response accuracy was high for the middle serial position in both Trigram and Pentagrams presented at fixation (i.e. letter position = 0), however, response times appeared longer for the pentagram compared to trigrams. This suggests that response times seem to be affected by an additional factor other than crowding and response accuracy, rather it is dependent on string length per se. It is conceivable this results reflects additional processing delays imposed by search times, which may explain the string length dependency. This observation is currently being addressed with greater detail in a separate study.

The conclusions drawn from this study will hopefully contribute to the understanding of the nature of the processing delays of letter recognition in the peripheral retina and slower reading speeds in eccentric viewing conditions.

Acknowledgements

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FIGURES

All error bars in all figures represent intervals of 95% confidence

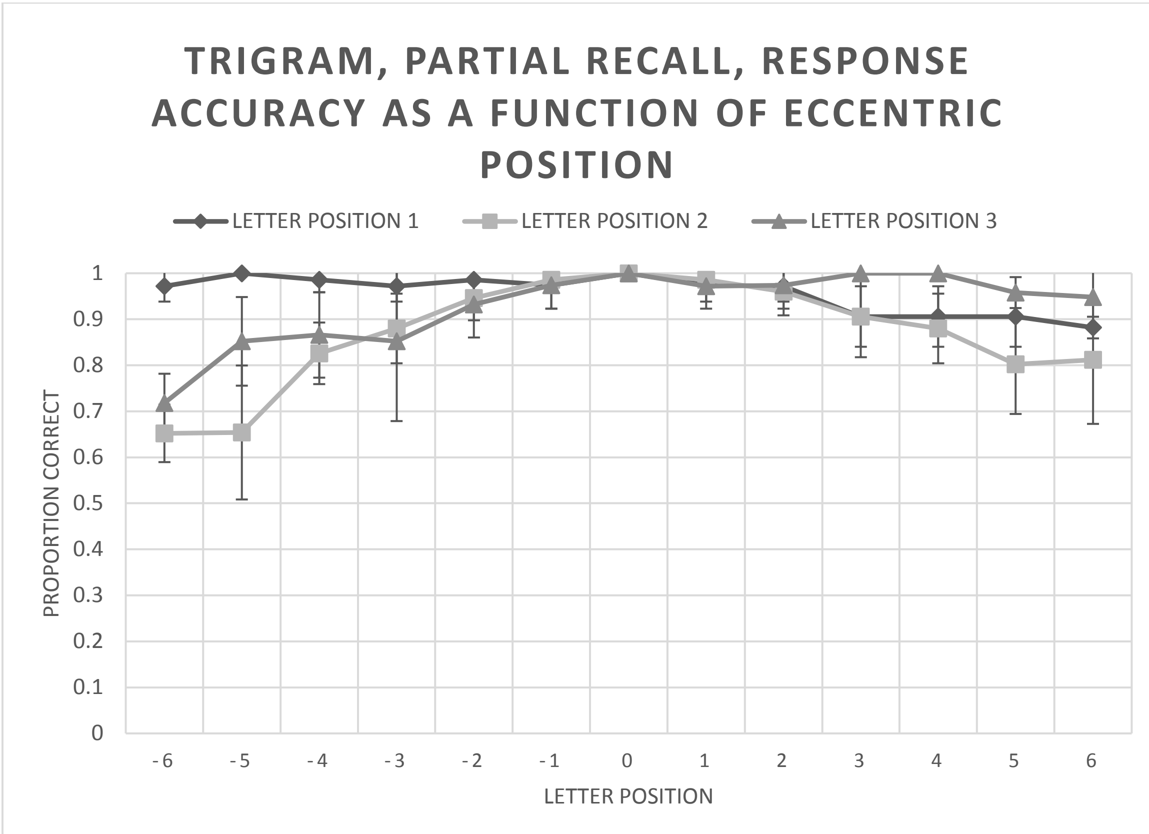

FIGURE 1

Figure 1 represents partial response accuracy variance across all 13 serial viewing positions for each letter within trigrams.

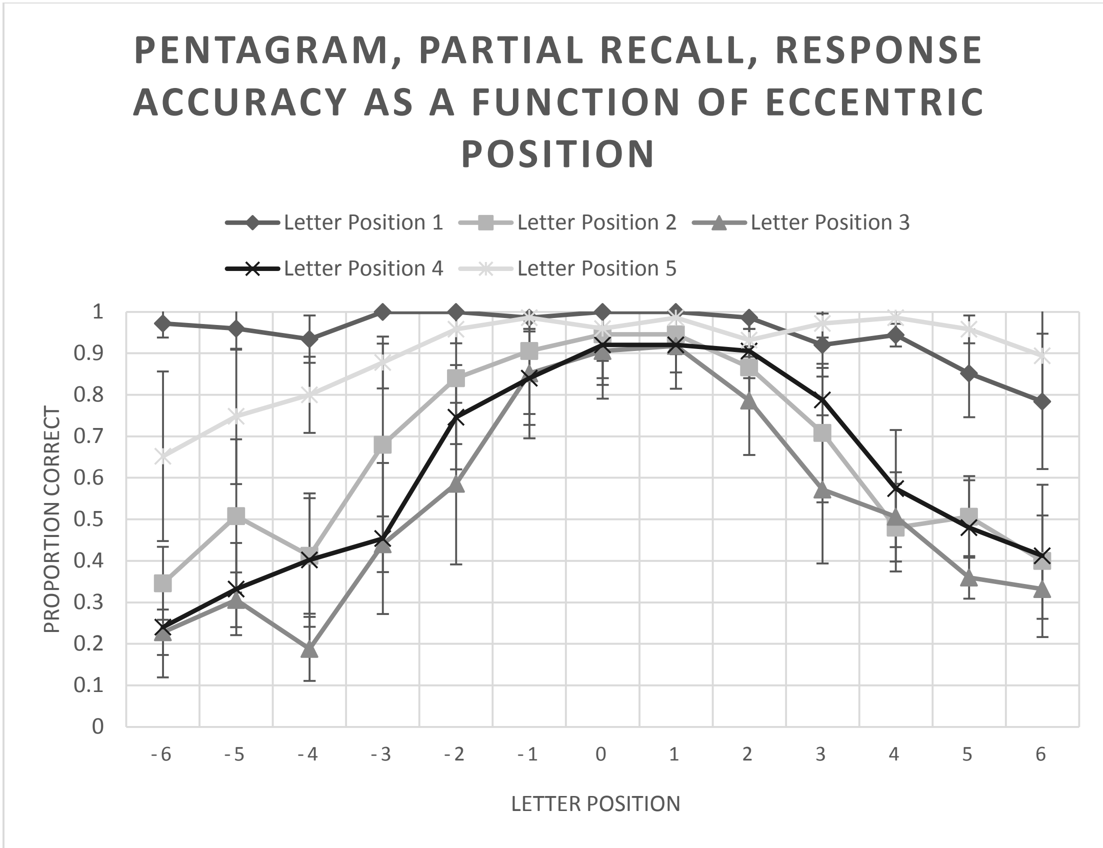

FIGURE 2

Figure 2 represents partial response accuracy variance across all 13 serial viewing positions for each letter within pentagrams.

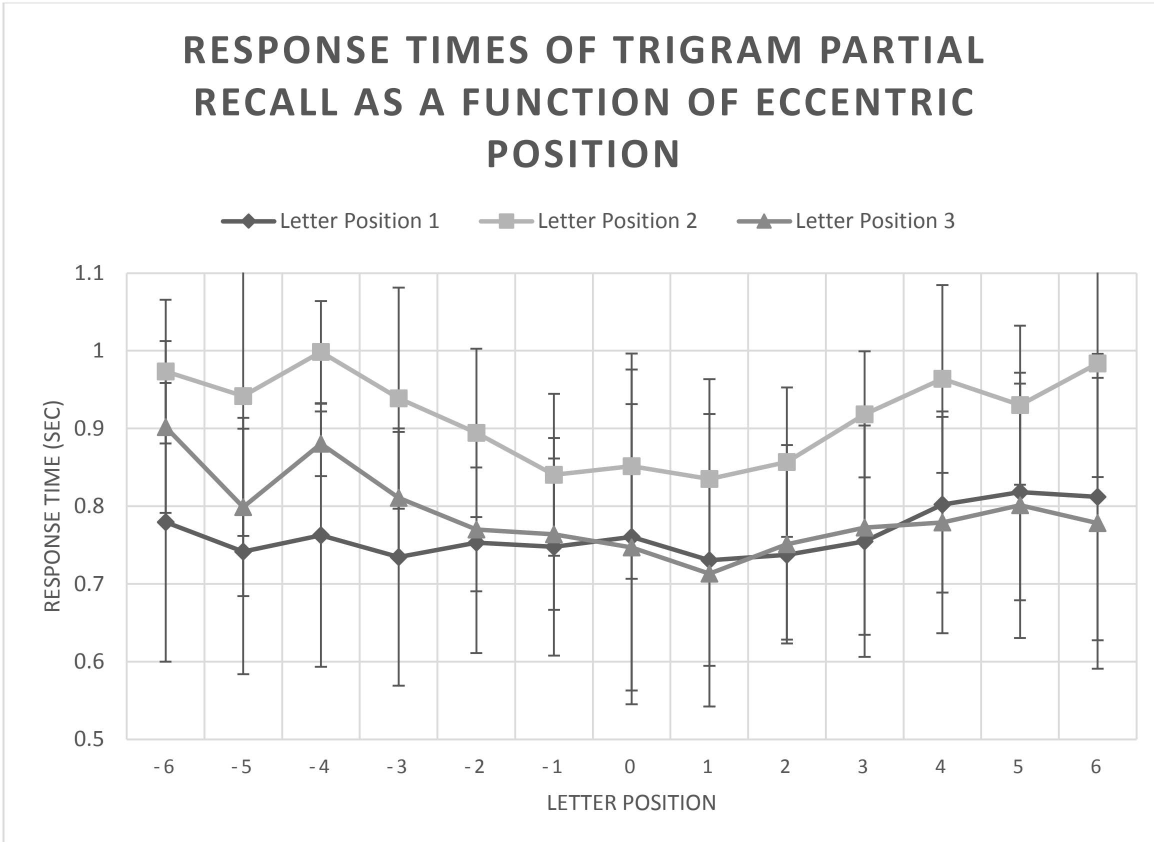

FIGURE 3

Figure 3 represents partial response times in all 13 serial viewing positions for each letter within trigrams.

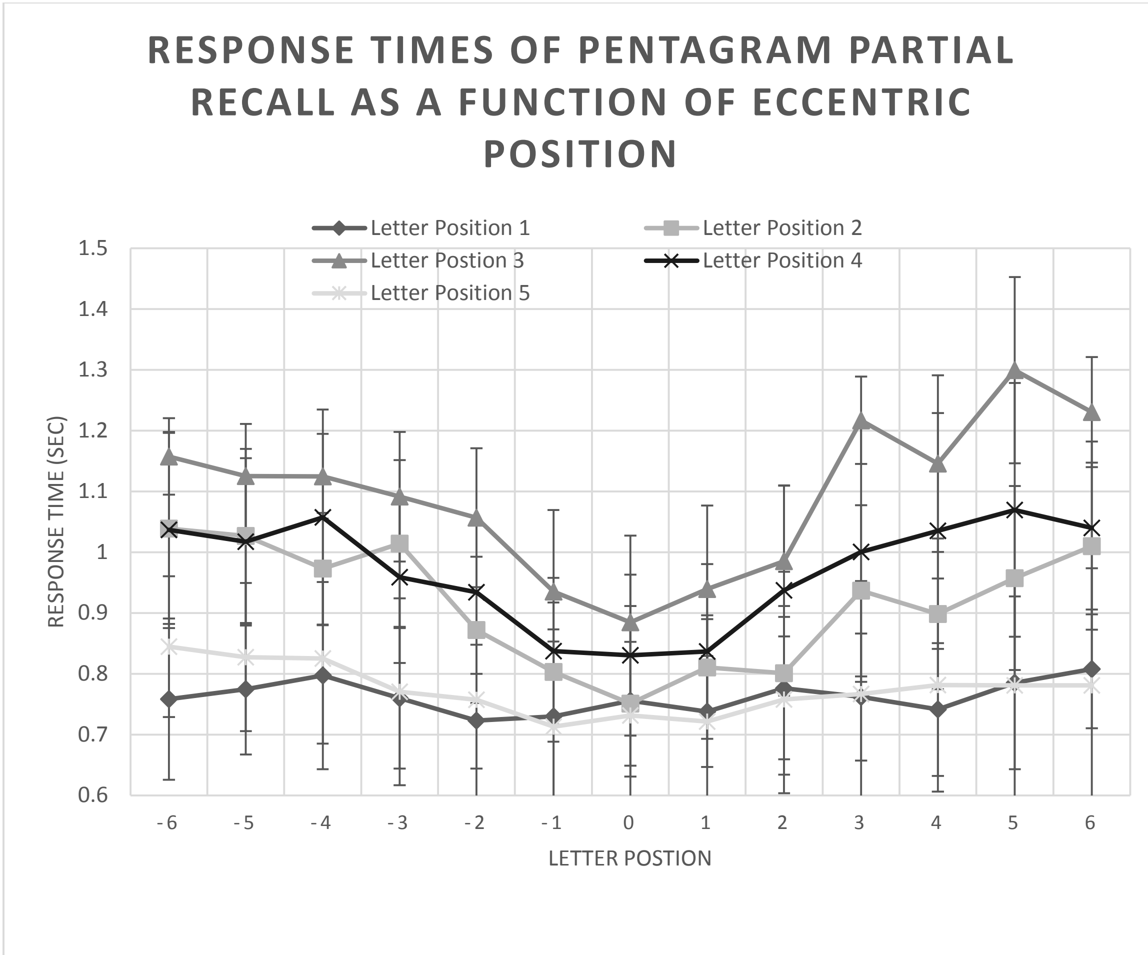

FIGURE 4

Figure 4 represents partial response times in all 13 serial viewing positions for each letter within pentagrams.

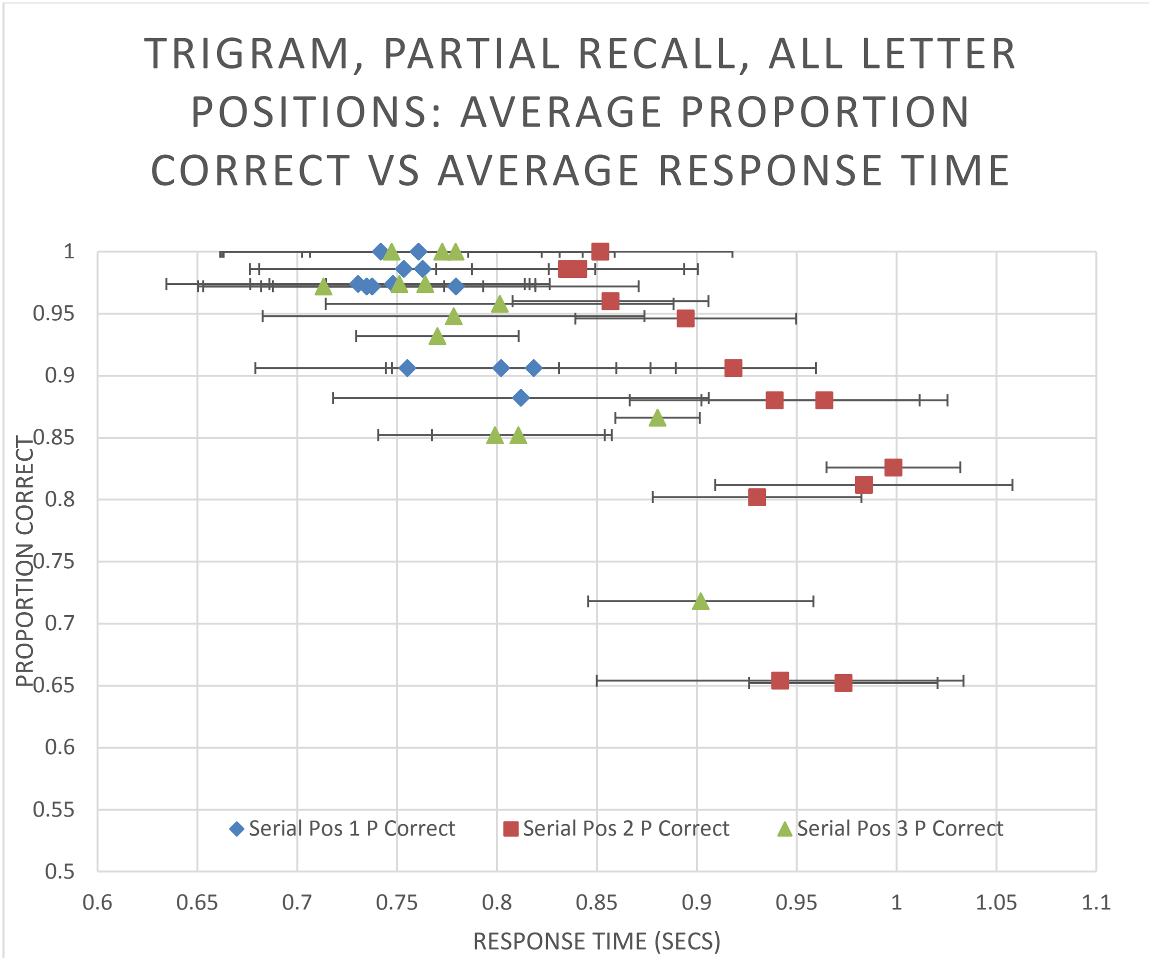

FIGURE 5

Figure 5 demonstrates the inverse relationship between response times and response accuracy for each serial letter position within trigrams in all 13 viewing positions.

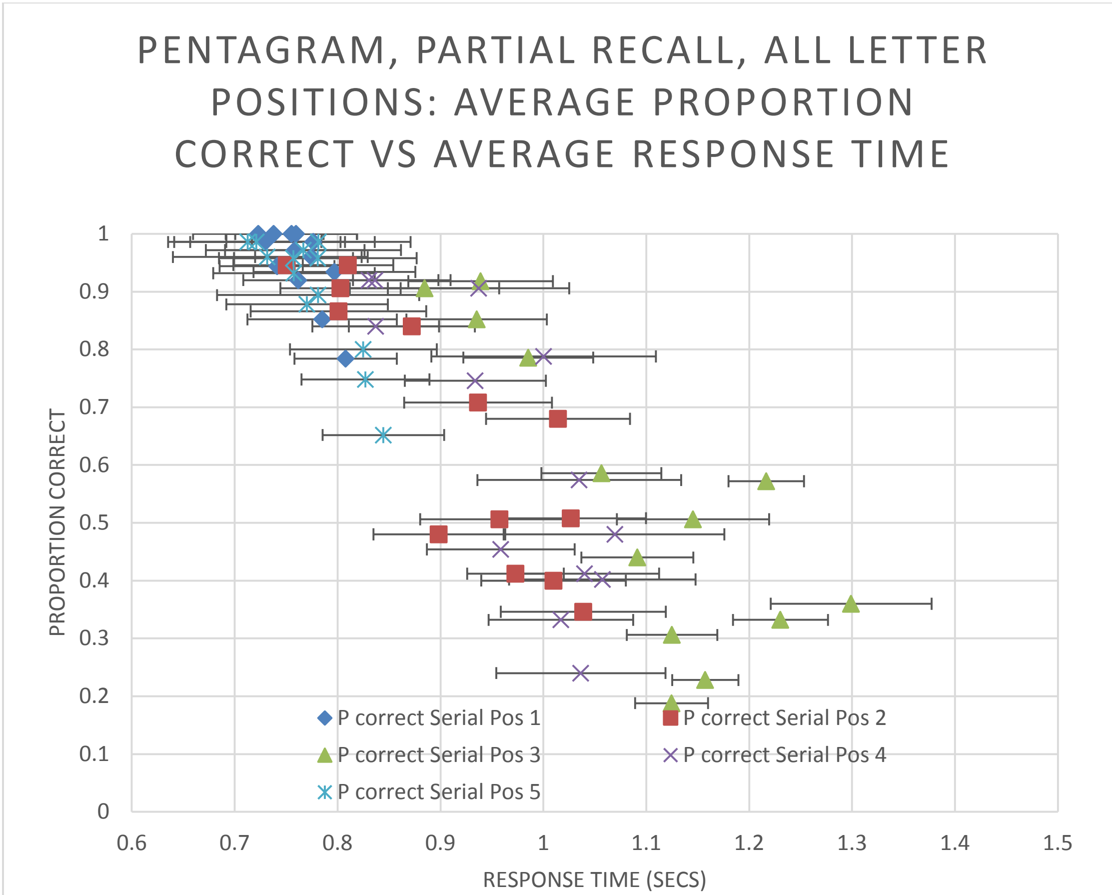

FIGURE 6

Figure 6 demonstrates the inverse relationship between response times and response accuracy for each serial letter position within pentagrams in all 13 viewing positions.

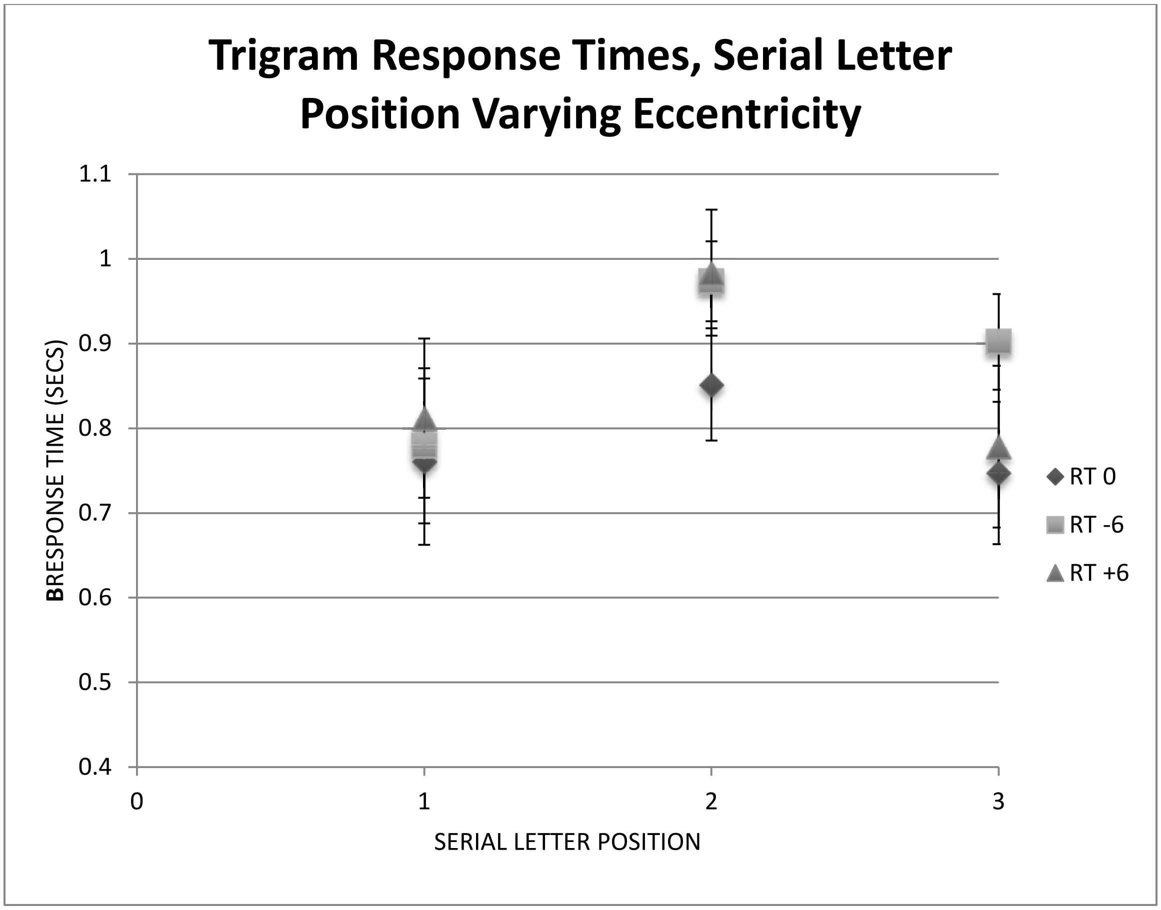

FIGURE 7

Figure 7 represents the variation in response times for all serial letter positions within trigrams for viewing positions -6 (most left) 0 (center) +6 (most right).

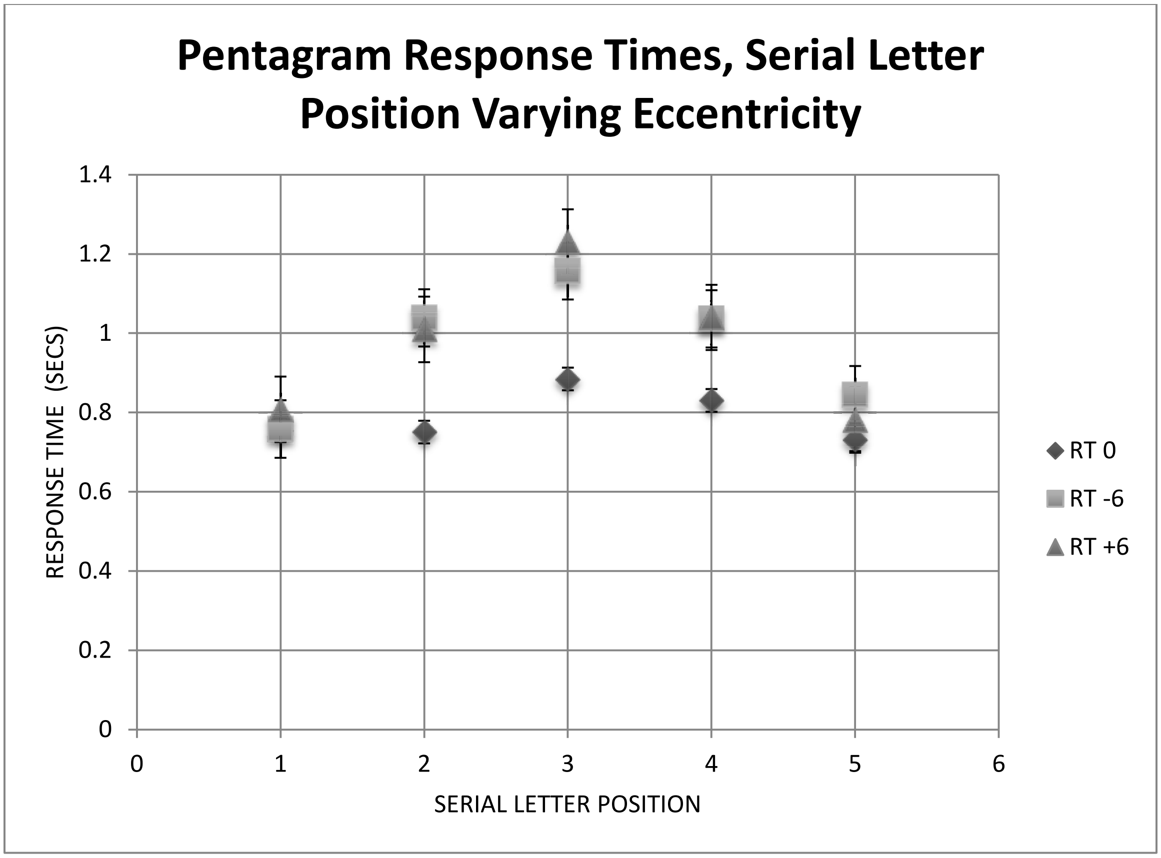

FIGURE 8

Figure 8 represents the variation in response times for all serial letter positions within pentagrams for viewing positions -6 (most left) 0 (center) +6 (most right).