Gaze sequences reveal how people gradually arrive at a solution to a word puzzle (anagram)

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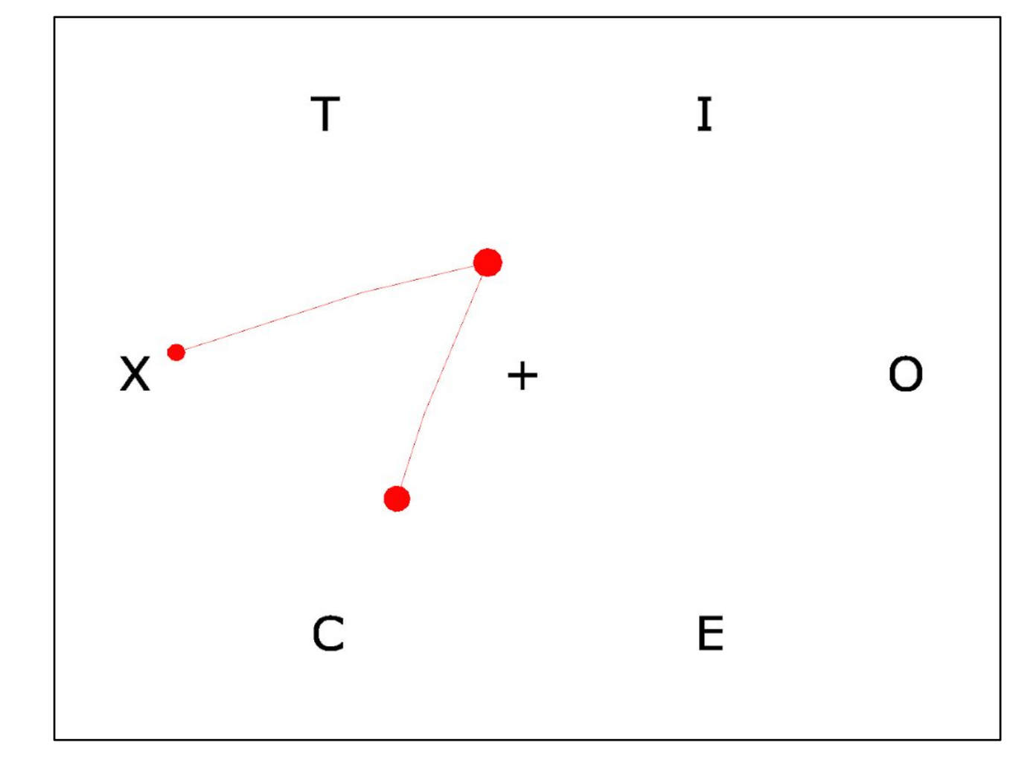
Introduction

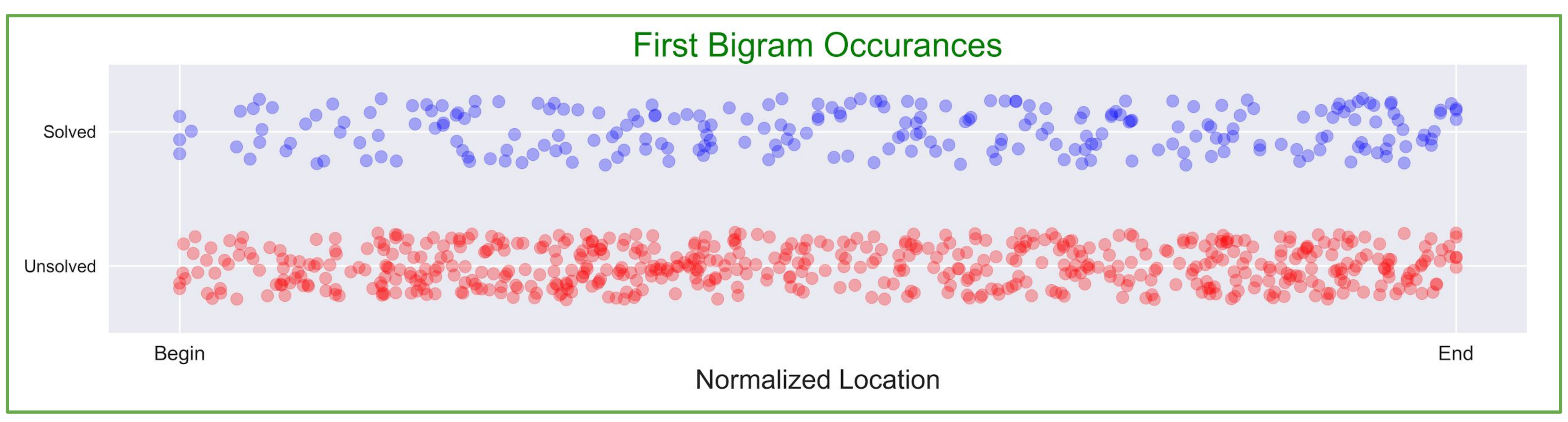
A Eureka ("a-ha") moment is like a culminating act of putting the last few pieces of a puzzle into the correct places, and it can only happen after extensive prior efforts. In other words, a solution to a complex cognitive problem tends to emerge gradually, rather than "pop out."

In this study, human subjects (N=29, college students) were asked to solve anagrams with 5 or 6 letters. As they were unscrambling letters to form a word, their gaze positions were recorded with a Tobii-60 eye tracker. An earlier eye-tracking study by Ellis et al. (2011) showed that approximately 2 seconds before reaching a solution, subjects gradually began to dwell more on solution letters than distractor letters, even when subjects reported that a solution suddenly emerged in their minds. We extend this experimental paradigm by analyzing gaze sequences, or letter combinations, that the subjects are considering during their solution-seeking process.

We show that the bigrams (two-letter combinations) at the beginning and the end of a solution word are particularly informative. The gaze frequency for those bigrams increases as the subject approaches a solution.



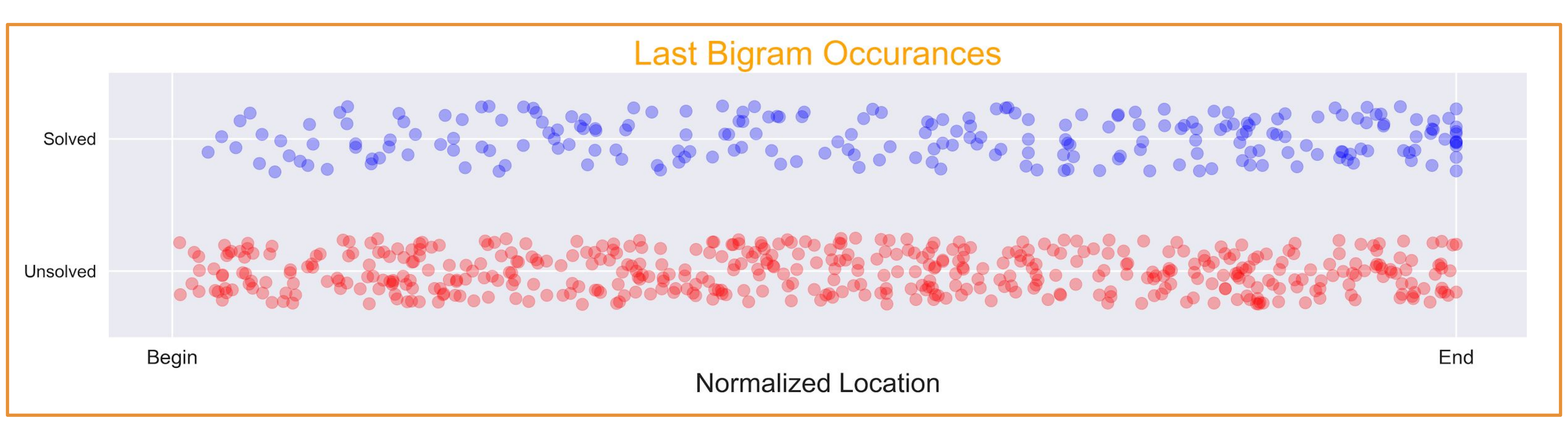
An example stimulus with a 6-letter anagram. Three gaze positions are shown in red. Can you find a solution to this anagram?



| Avg. Loc. = 0.72

UJONRIUJNOIURUJNJOUIRNOJUINOJUJORINRURUJIORNRIOJURIORJUNONJURNRJU

| Avg. Loc. = 0.66



Shown on the left is a sample sequence of letters seen by a subject.

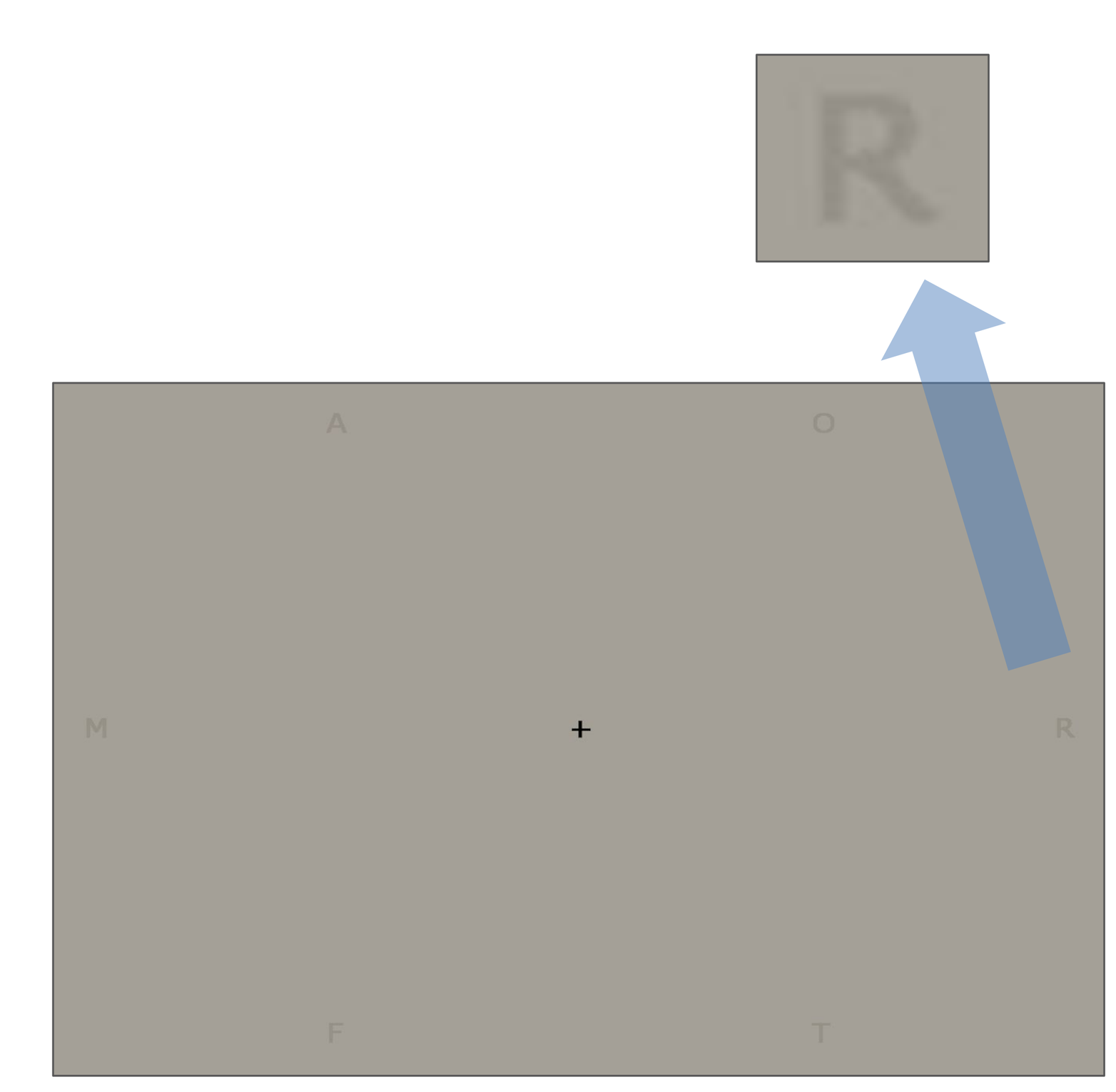
Solution Word:
JUNIOR

JU = First Bigram
OR = Last Bigram

The frequency of gaze on the first and last solution word bigrams increases, as the subject gets closer to recognizing the solution word.

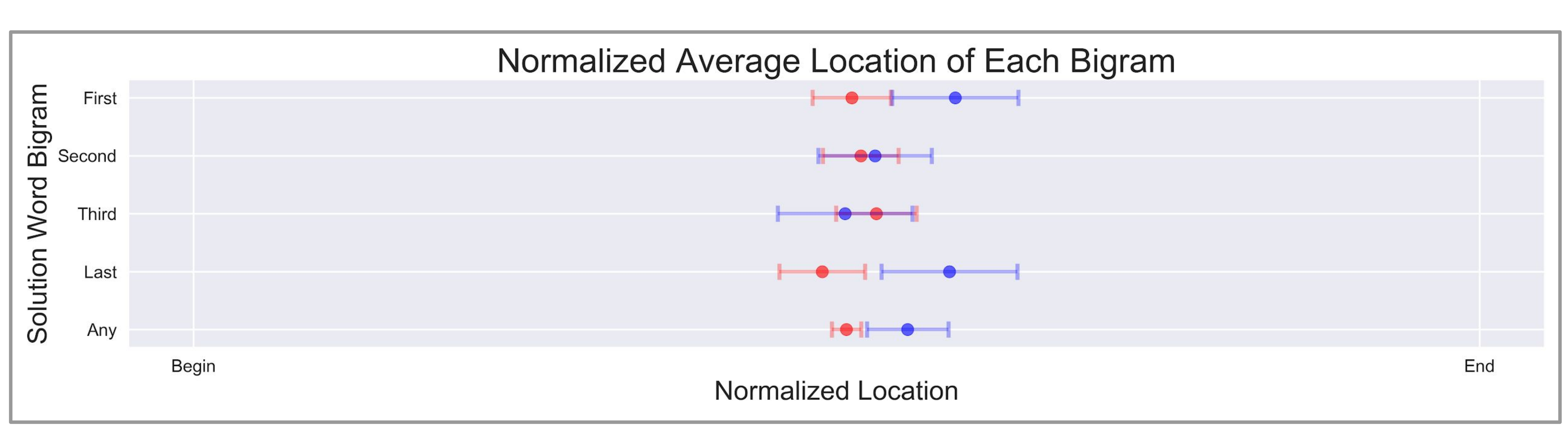
Method Improvement: Dealing with ambiguous fixations.

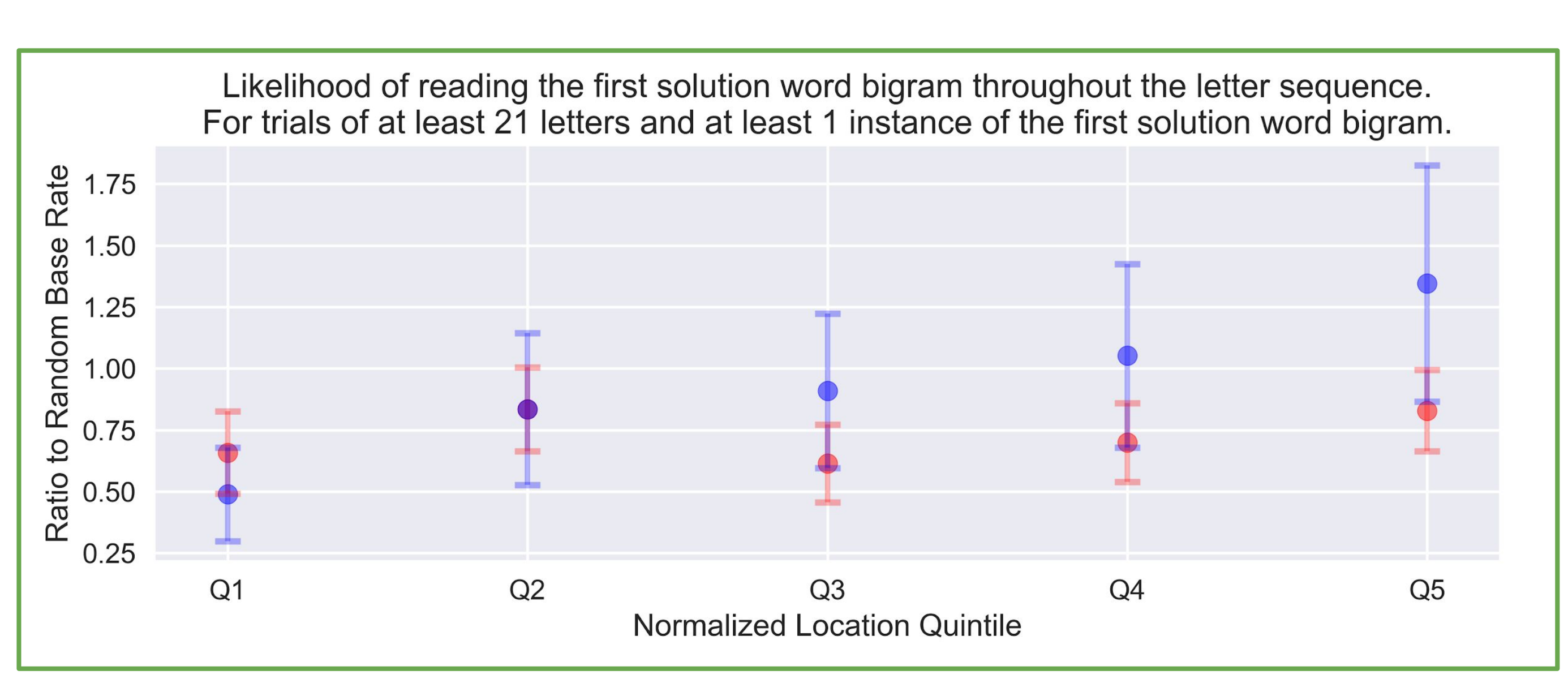
During the pilot experiments, we noticed that subjects frequently did not look directly at the letters on the screen, presumably because they could still read the letters with their non-foveal vision. As a result, it was difficult to infer which letters were being considered by the subjects. We increased the distance between letters and decreased the image contrast and font size, making individual letters more difficult to read with non-foveal vision. These changes led to a significant improvement in the quality of the data.

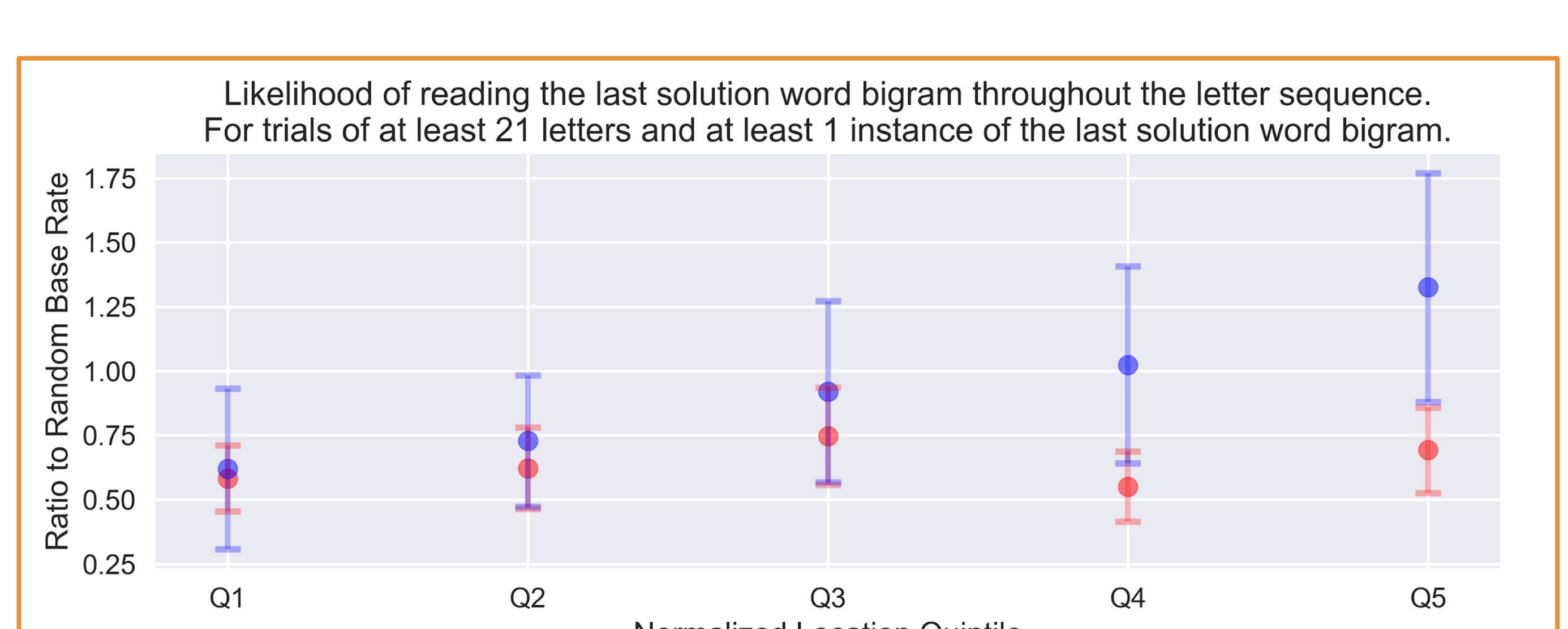


Results

For each trial, we calculated the average normalized location of solution word bigrams within the gaze sequence. For the **solved** trials, the average location of the **first** and **last** in-word bigrams were significantly closer to the end of the gaze sequence than for the **unsolved** trials. The error bars indicate 95% confidence intervals.







Discussion

Our results suggest that the first and last bigrams of the solution word are important pieces of partial solution knowledge. The likelihood of viewing these bigrams (and therefore testing out various hypotheses) increases gradually and is significantly higher close to the end of the gaze sequence for solved trials than unsolved trials.

In future experiments, we will analyze the gaze frequency to common bigrams in the English language, such as "th" or "er," and see how prior linguistic knowledge influences the problem-solving strategy.

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References
- Ellis et al. (2011). "Eye movements reveal solution knowledge prior to insight" Consciousness and Cognition, 20, 768-776.