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

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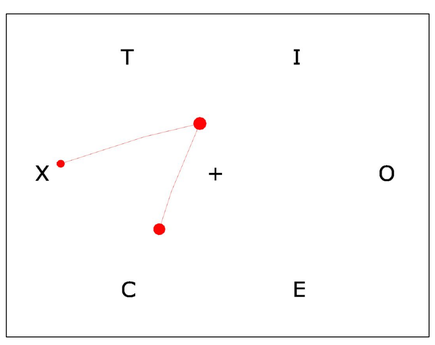
Abstract

In many problem-solving tasks, a solution tends to emerge gradually, rather than "popping out". Even a Eureka-moment is compared to a culminating act of putting the last puzzle piece in place after the extensive prior work of assembling most of the pieces [Cite: "Myth of Innovation"].

In this study, subjects were asked to unscramble randomly-scattered letters that formed a word (anagram), while their gaze locations were measured by an eye tracker. A similar eye-tracking study [Ellis et al., 2011] revealed that 2.4 seconds before reaching a solution, subjects gradually began to view solution letters for longer than distractor letters, illustrating that solution knowledge forms gradually rather than suddenly. This was the case even when subjects reported the solution as suddenly 'popping out', indicating that the partial solution knowledge was beneath the threshold for awareness.

We extended this experimental paradigm by analyzing gaze sequences which reveal letter combinations that a subject is considering during the solution-seeking process. We show that the first and last two-letter combinations (bigrams) that are part of the solution word are viewed more frequently prior to a solution.



An example stimulus with a 6-letter anagram. Three gaze positions are shown in red.

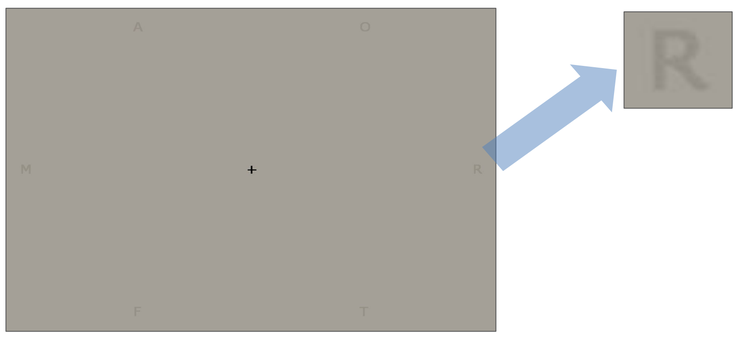
Can you find a solution to this anagram?

Methods

- Subjects: 29 undergraduate students
- Tobii T60 Eye Tracker with Tobii Studio
- One candy reward for every solved anagram
- Data analysis in Python (pandas)

Method Improvement: handling ambiguous fixations.

During pilot experiments, we found that subjects tended to not look directly at the letters on the screen (presumably because they could still read the letters using their non-foveal vision). As a result, it was difficult to infer which letters subjects were looking at. We lowered the contrast and changed the size and location of the letters, making them more difficult to read with peripheral vision. These changes led to a significant improvement in the quality of the data.



Results

Example gaze sequence (solved trial):

UJONRIUJNOIURUJNJOUIRNO**JU**INO**JU**J**OR**INRURUJI**OR**NRIO**JU**RI**OR**JUNON**JU**RNR**JU**

Solution Word: JUNIOR

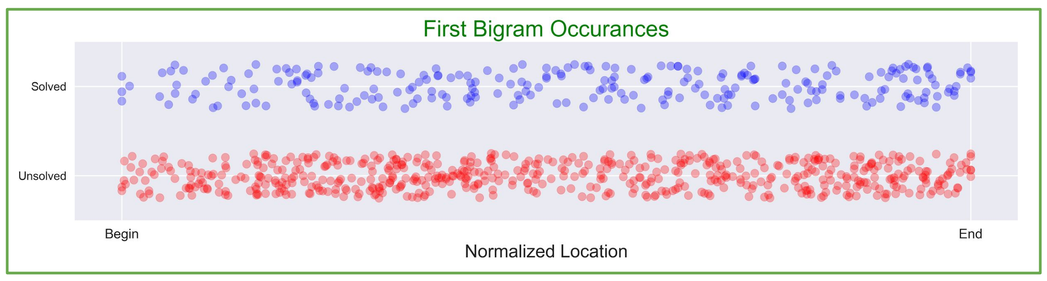
First Bigram Last Bigram

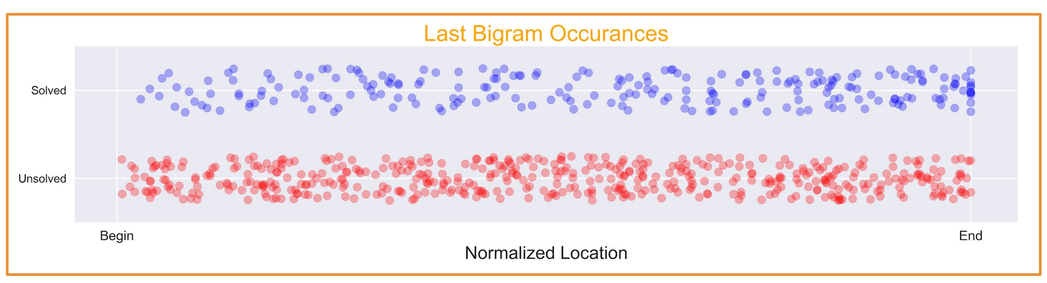
JU average location = 0.72 OR average location = 0.66

For solved trials, the first and last solution word bigrams tend to be located closer to the end of the gaze sequence.

Solved Trial Unsolved Trial

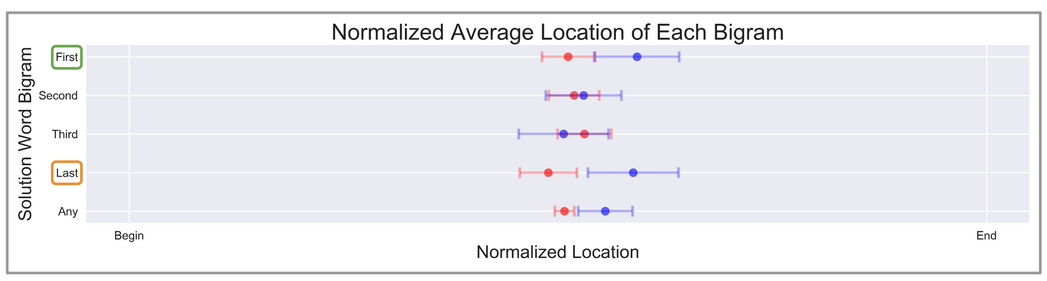
The following two plots give the normalized location in the gaze sequence of all **first** and **last** solution word bigrams detected in **solved** and **unsolved** trials.



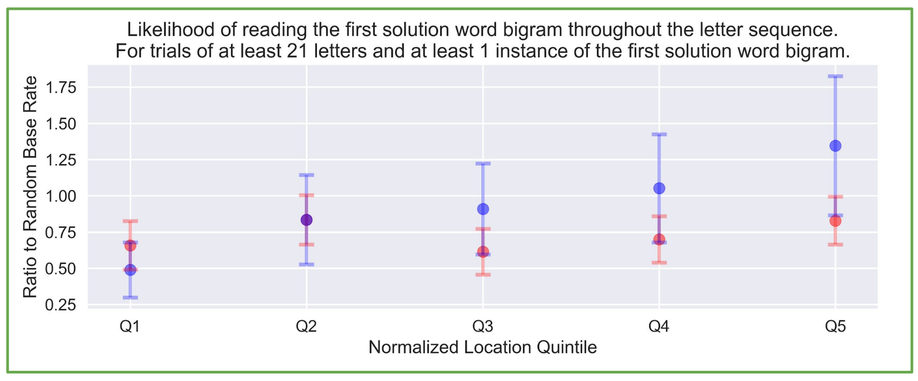


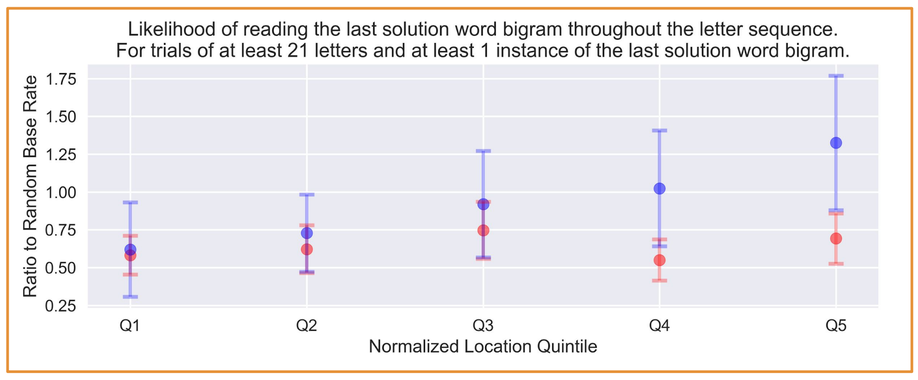
The average normalized location of the **first** and **last** solution word bigrams is significantly greater in **solved trials** than in **unsolved** trials.

In all following plots, dots give averages and error bars give 95% confidence intervals.



In the latter portion of the gaze sequence, the likelihood of reading the **first** and **last** solution word bigrams becomes significantly greater in **solved** trials than in **unsolved** trials.





The significance of the average location and likelihood remain even when removing the final gaze sequences to account for the possibility of subjects checking their solutions (which they were instructed not to do).

Discussion

Our results suggest that the first and last bigrams of the solution word are important pieces of partial solution knowledge. This partial solution knowledge is detected early in the problem-solving process, likely before it is accessible to subjective phenomenal awareness [Ellis et al., 2011]. In future experiments, we will seek to compare the relevance to solution knowledge of more frequent bigrams in the English language - such as 'th' or 'er' - to less frequent bigrams.

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References

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

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