The role of character information in the programming of return-sweep saccades during reading

Overview

Study Information

Title

Provide the working title of your study. It may be the same title that you submit for publication of your final manuscript, but it is not a requirement.

The role of character information in the programming of return-sweep saccades during reading

Authors

Martin R. Vasilev, Timothy J. Slattery, Victoria Adedeji , Calvin Laursen, Marcin Budka

Description

Please give a brief description of your study, including some background, the purpose of the study, or broad research questions. (optional)

Return-sweeps are the largest commonly occurring saccades in reading. They move the eyes from the end of one line to the beginning of the next (Rayner, 2009). It is known that readers generally fixate a few characters away from the margin rather than on the first letter on the line after a return-sweep and a corrective saccade (Hoffmeister, 1998). Furthermore, line length influences return-sweep landing position. With longer lines, the return-sweep lands further to the right on the new line. According to Tinker and Heller, optimal line length changes depending on a reader's ability to programme an accurate return-sweep leading to fewer corrective saccades (as cited in Hoffmesiter, Heller & Radach, 1999). It also seems that font size has a similar impact on the landing site of the return-sweep across multiple writing systems where an increase in font size makes reading clearer and may cause the return-sweep to land even further to the right as the reader compensates for the larger letters (Shu et al., 2010; Anstis, 1974; Hoffmeister, 1998).

However, little is known about how these saccades are programmed and executed especially since readers do not have the benefit of viewing words at the start of the next line in the parafovea (Parker, Slattery & Julie, 2017). Morrison & Rayner (1981) found that intra-line saccades are programmed based on the number of characters rather than visual angle. They manipulated the apparent font size by changing the viewing distance of the text and found the amplitude of intra-line saccades (i.e. non-return-sweeps) remained the same in terms of the number of characters traversed.

With forward intra-line saccades, there is a large body of evidence suggesting that readers are targeting the centre of an upcoming word (McConkie, Kerr, Reddix, & Zola, 1988; Rayner, 1979). However, readers appear to aim their return-sweep saccades relative to the leftmost letter on the targeted line rather than to a position within a targeted word, such as its centre (Slattery & Vasilev, 2019). Therefore, the question remains as to whether return-sweep saccades are targeted as a function of the number of characters from the start of a line or as a function of the degrees of visual angle from the start of a line. Another question arises as to how both font size and line length together affect return-sweep targetting as a whole as for the most part, these have been looked at separately in previous studies.

To investigate these questions, we will be employing a 2 by 2 manipulation of font size (12 pixel vs. 16 pixel letter width) and line length (16 degrees vs. 26 degrees of visual angle) while controlling for the line initial word and the last four words on the first line. Our chosen manipulation ensures that, for a given line length, both font sizes will subtend the same visual angle but the larger font will have fewer characters than the smaller font.

References:

Anstis, S. (1974). A chart demonstrating variations in acuity with retinal position. Vision Research, 14(7), pp.589-592.

Hofmeister, J. (1998). Über Korrektursakkaden beim Lesen von Texten und bei leseähnlichen Aufgaben. Aachen: Shaker Verlag.

Hoffmesiter J., Heller D., & Radach R. (1999) The Return-sweep in Reading. In: Becker W., Deubel H., Mergner T. (eds) Current Oculomotor Research. Springer, Boston, MA.

McConkie, G. W., Kerr, P. W., Reddix, M. D., & Zola, D. (1988). Eye movement control during reading: I. The location of initial eye fixations on words. Vision research, 28(10), 1107-1118.

Parker, A., Slattery, T. and Kirkby, J. (2019). Return-sweep saccades during reading in adults and children. Vision Research, 155, pp.35-43.

Pollatsek, A., Juhasz, B., Reichle, E., Machacek, D. and Rayner, K. (2008). Immediate and delayed effects of word frequency and word length on eye movements in reading: A reversed delayed effect of word length. Journal of Experimental Psychology: Human Perception and Performance, 34(3), pp.726-750.

Rayner, K. (1979). Eye guidance in reading: Fixation locations within

words. Perception, 8(1), 21-30.

Rayner, K. (2009). The 35th Sir Frederick Bartlett Lecture: Eye movements and attention in reading, scene perception, and visual search. Quarterly Journal of Experimental Psychology, 62(8), pp.1457-1506.

Shu, H., Zhou, W., Yan, M. and Kliegl, R. (2010). Font size modulates saccade-target selection in Chinese reading. Attention, Perception, & Psychophysics, 73(2), pp.482-490.4

Slattery, T. J., & Vasilev, M. R. (2019). An eye-movement exploration into return-sweep targeting during reading. Manuscript under review.

Hypotheses

List specific, concise, and testable hypotheses. Please state if the hypotheses are directional or non-directional. If directional, state the direction. A predicted effect is also appropriate here. If a specific interaction or moderation is important to your research, you can list that as a separate hypothesis.

Hypotheses about landing positions:
1) Main effect of line length: longer lines should result in return-sweep landing positions shifted to the right and an increase in the percentage of the corrective leftward saccades immediately after the return-sweep.

2) Main effect of font size;
- 1 alt. is that return sweeps are executed only by visual angle from the margin. If this the case, there should be no main effect of font size because participants will land at the same location (in visual angle relative to the left margin) regardless of font size.
- 2 alt. if there is an influence of the number of characters, then with larger font the landing position should shift to the right relative to the smaller font.

3. Interaction between line length and font size: If character information plays a role, then we predict an interaction between font size and line length. More specifically, the font size effect should become smaller with an increase in line length. This is because, with longer lines, letters at the start of the line will be further into peripheral vision, therefore character information will be a less reliable cue for programming return-sweeps.

Hypotheses about saccade lengths:
4. Since intra-line saccades are targeted towards word's OVP, the progressive saccade length in visual angle should become larger with increasing font size (Slattery, Yates, & Angele, 2016; Slattery & Rayner, 2013). However, the length of return-sweep saccades should be either shorter when fonts are larger (see hypothesis 2 [alt2] above), or there should be no difference in return-sweep saccade lengths due to font size [alt1]. This should therefore result in an interaction between font size and saccade type (intra-line vs. return-sweep).

Hypotheses about corrective saccade percentage:
5. Based on Hofmeister (1998), we predict that the frequency of corrective saccades will decrease in the bigger compared to the smaller font. Additionally, we predict a main effect of line length, with greater frequency of corrective saccades for the long compared to the small line length. This is because there is greater amount of saccadic range error with an increase in line length.

6. If the reduction of corrective saccades with larger fonts, as reported by Hofmeister (1998), is due to there being fewer characters to the left of fixation, then there should be an interaction between line length and font size on corrective saccade rates. This is because, at a given return-sweep landing site (in visual angle relative to the left margin), there will be more characters to the left with the small font than with the large font and this difference will grow larger the further to the right the return sweep lands. With longer lines, landing sites shift to the right thereby yielding a larger font size effect.

Design Plan

Study type

Please check one of the following statements

- Experiment - A researcher randomly assigns treatments to study subjects, this includes field or lab experiments. This is also known as an intervention experiment and includes randomized controlled trials.

Blinding

Blinding describes who is aware of the experimental manipulations within a study. Mark all that apply.

- No blinding is involved in this study.

Is there any additional blinding in this study?

Blinding (Other) (optional)

No

Study design

The design will be 2 x 2 within-subject factorial design with font size (small vs big) and line length (short vs long) as the two factors. See below for counter-balancing plan.

(optional)

- No files selected

Randomization

If you are doing a randomized study, how will you randomize, and at what level? (optional)

The assignment of items to the four conditions will be counter-balanced across participants with a full Latin square design. The font size manipulation will be blocked and counter-balanced across participants. All items will appear in pseudo-random order in each of the two blocks.

Sampling Plan

Existing Data

Preregistration is designed to make clear the distinction between confirmatory tests, specified prior to seeing the data, and exploratory analyses conducted after observing the data. Therefore, creating a research plan in which existing data will be used presents unique challenges. Please select the description that best describes your situation. Please see https://cos.io/prereg for more information.

- Registration prior to creation of data

Explanation of existing data

If you indicate that you will be using some data that already exist in this study, please describe the steps you have taken to assure that you are unaware of any patterns or summary statistics in the data. This may include an explanation of how access to the data has been limited, who has observed the data, or how you have avoided observing any analysis of the specific data you will use in your study. (optional)

N/A

Data collection procedures

We will recruit participants from the Bournemouth community who are English speakers. Participants should be between 18-50 years of age, have normal or corrected-to-normal vision, and no prior history of reading disorders. Participants will be recruited from SONA or through posters and word of mouth. Participants will be compensated either with course credits or a payment for the duration of the study.

(optional)

- No files selected

Sample size

Describe the sample size of your study. How many units will be analyzed in the study? This could be the number of people, birds, classrooms, plots, interactions, or countries included. If the units are not individuals, then describe the size requirements for each unit. If you are using a clustered or multilevel design, how many units are you collecting at each level of the analysis?

multilevel design, how many units are you collecting at each level of the analysis?

We will recruit 64 participants for this study.

Sample size rationale

This could include a power analysis or an arbitrary constraint such as time, money, or personnel. (optional)

We calculated the expected effect size for the line length and font size manipulation using the results from Hofmeister's (1998) Experiments 1 and 2, respectively. The font size effect size was d= 0.658 for landing position and d= 0.316 for the probability of making a corrective saccade. The line length effect size was d= 1.216 for landing position and d= 2.051 for the probability of making a corrective saccade. The effect size of the interaction between font size and line length, if it exists, is unknown as no studies on the topic have been conducted. However, we made the somewhat conservative assumption that the interaction effect size for landing position may be twice as small as the main effect of font size (i.e., d= 0.65/2= 0.325). We focused on the landing position model for the interaction term as this is of main theoretical interest in the present study.

Statistical power was calculated using the PANGEA software (https://jakewestfall.shinyapps.io/pangea/), which specifies participants and items as crossed (random) factors in the calculation. This is necessary as the data will be analysed with Linear Mixed Models, where participants and items will be added as random effects. Assuming an alpha level of .05, the power analysis indicated that 64 participants are needed to achieve 80% power for the smallest effect size, as recommended by Cohen (1988).

Stopping rule

If your data collection procedures do not give you full control over your exact sample size, specify how you will decide when to terminate your data collection. (optional)

We will finish data collection after all planned participants have been tested.

Variables

Manipulated variables

(optional)

We manipulated two variables:

1) The length of the first line of text in degrees per visual angle. The first line will be either 16 or 26 degrees per visual angle.
2) The font size of the text. The text will be formatted in a fixed-width Consolas font where each letter is either 12 or 16 pixels in width.

Note: In order to manipulate these variables it was necessary to manipulate the number of letters on the first line of text.

(optional)

- No files selected

Measured variables

We will use the following dependent variables:

1) Landing position on the second line relative to the start of this (second) line. Additionally, we will also analyse the landing position of intra-line saccades that occur with a single line.

2) Probability of making a corrective saccade. Cases where the reader's return sweep is immediately followed by another leftward saccade will be coded as 1; cases where there is a rightward saccade following a return sweep will be coded as 0.

3) Saccade length- We will measure the length of individual saccades that participants make (both return-sweep and intra-line saccades that occur within a single line).

(optional)

- No files selected

Indices

(optional)

N/A

(optional)

- No files selected

Analysis Plan

Statistical models

We will analyse the data using (Generalised) Linear Mixed Models in R using the lme4 package. Participants and items will be added as random intercepts and font size and line length will be added as random slopes for both participants and items. The fixed effects in the models will be font size, line length, and their interaction. In the return

effects in the models will be font size, line length, and their interaction. In the return sweep models, we will also add launch position as a covariate. If a model fails to converge, random slopes will be removed as required in order to ensure convergence.

The lme4 syntax for the models will be as follows:

# landing position:
LM1= lmer(land_pos ~ font_size * line_length * launch_pos + (font_size + line_length|subject) + (font_size + line_length|item), data= data, REML= T)

# probability of making a corrective saccade:
GLM1= glmer(pCorr_sacc ~ font_size * line_length * launch_pos + (font_size + line_length|subject) + (font_size + line_length|item), data= data, family= binomial)

# Saccade length (both intra-line and return-sweep):
LM2= lmer(sacc_length ~ font_size * line_length * sacc_type + (font_size + line_length|subject) + (font_size + line_length|item), data= data, REML= T)

(optional)

- No files selected

Transformations

If you plan on transforming, centering, recoding the data, or will require a coding scheme for categorical variables, please describe that process. (optional)

In models where launch site is included as a covariate, it will be centred at 0 to improve the scaling of the model.

Inference criteria

What criteria will you use to make inferences? Please describe the information you'll use (e.g. specify the p-values, Bayes factors, specific model fit indices), as well as cut-off criterion, where appropriate. Will you be using one or two tailed tests for each of your analyses? If you are comparing multiple conditions or testing multiple hypotheses, will you account for this? (optional)

We will use frequentist (Generalised) Liner Mixed models and use the t/z values to make inferences. When the absolute t or z values is equal to, or greater than 2, the effect will be considered as statistically significant. We will also report effect sizes in Cohen's d.

Data exclusion

How will you determine which data points or samples if any to exclude from your analyses? How will outliers be handled? Will you use any awareness check? (optional)

Participants will be replaced if their comprehension accuracy is less than 75% or if they contribute less than 50% of trials to the data analysis.

Fixations and saccades that contain a blink/ track loss, or are immediately preceded or

followed by a blink/ track loss will be discarded.

Fixations shorter than 80 ms that occur within 14 pixels of a temporally adjacent fixation will be combined with each other (this is the mean of the two font conditions). Any remaining fixations less than 80 ms will be discarded. Fixations longer than 1000 ms and their adjacent saccades will be deleted from the data. If the outlier occurs immediately before or after the return sweep saccade, the whole trial will be removed. If the outlier occurs within the line (intra-line fixation), the trial will be kept but the outlier fixation will be deleted.

Missing data

How will you deal with incomplete or missing data? (optional)

If a subject does not complete all trials in the experiment, they will be replaced.

Exploratory analysis

If you plan to explore your data set to look for unexpected differences or relationships, you may describe those tests here. An exploratory test is any test where a prediction is not made up front, or there are multiple possible tests that you are going to use. A statistically significant finding in an exploratory test is a great way to form a new confirmatory hypothesis, which could be registered at a later time. (optional)

We will use Generalized Additive Mixed Models to explore how trial number influences the effects. We would expect that readers who begin with the small font block will grow accustomed to land at a certain location close to left margin in terms of visual angle. When they switch to the big font condition, they will gradually learn to shift their landing position further to the right due to the fact that the letters will be bigger and occupy a greater area. We expect the opposite trend to occur for participants in the other block order (first big font, and then small font).

Other

Other

If there is any additional information that you feel needs to be included in your preregistration, please enter it here. Literature cited, disclosures of any related work such as replications or work that uses the same data, or other context that will be helpful for future readers would be appropriate here. (optional)