



Crossed Eye Fixations in Reading are Real

Antje Nuthmann¹ & Reinhold Kliegl²

¹University of Edinburgh (UK)

²University of Potsdam (Germany)



An examination of binocular reading fixations based on sentence corpus data

A. Nuthmann, & R. Kliegl

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Introduction

In reading, the eyes do not necessarily fixate the same point within a word (Heller & Radach, 1999). Starting point for the present work was the cursory observation that in our sentence corpus data the left eye frequently fixated ahead of the right eye (Kliegl et al., 2006). This dominance of horizontally crossed over uncrossed fixation disparities is opposite to what has been observed in other studies (e.g., Liversedge et al., 2006, using two separate DPI eye trackers). Therefore, one objective of the present work was to establish the validity of this seemingly odd data pattern. Besides, we sought to extend the (sparse) literature on binocular coordination in reading while drawing inspiration from basic oculomotor research on binocular coordination.



Materials and Methods

Material: Potsdam Sentence Corpus (Kliegl et al., 2006)

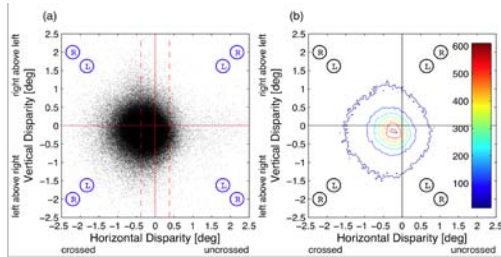
- 144 single unrelated German sentences comprising 1138 words
- valid data from 225 readers (age range: 16 to 84 years)

Apparatus: SR Research EyeLink I (250 Hz) and EyeLink II (500 Hz) Systems

- binocular calibration
- viewing distance: 50 cm (73 readers) vs. 60 cm (152)
- letters subtended 0.38° and/or 0.45° of visual angle
- ca. 200,000 binocular fixations

Results: The 2-dimensional fixation disparity ball

A binocular fixation consists of two fixation locations, one for the left eye (L_{xy}) and one for the right eye (R_{xy}), while a given fixation location has a horizontal x and a vertical y component. Fixation disparity was defined as the difference between right- and left-eye fixation positions, calculated for the horizontal and vertical dimensions, $D_{xy} = R_{xy} - L_{xy}$.

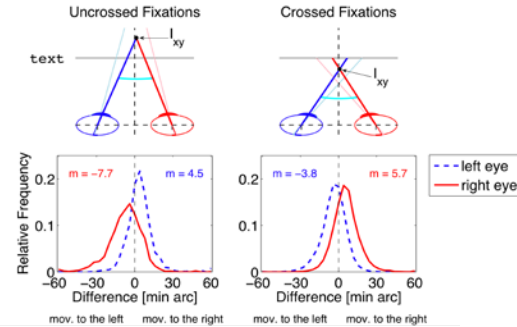


alignment proportions	crossed	aligned*	uncrossed	mean horizontal fixation disparity
Start	46%	50%	4%	1.22 char
End	39%	58%	3%	1.03 char

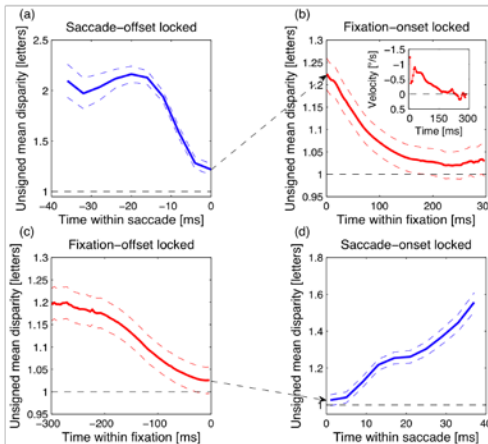
*aligned fixations: both eyes are within 1 character of each other (red band in panel a)

Monocular contributions to intra-fixational vergence differ for crossed vs. uncrossed fixations

The artefact hypothesis implies that a significant proportion of the observed crossed fixation disparities are not true crossed disparities. In order to counter this argument, we (1) identified circumstances where crossed and uncrossed fixations should differ in their oculomotor response, and (2) demonstrated that the data showed the predicted dissociation.

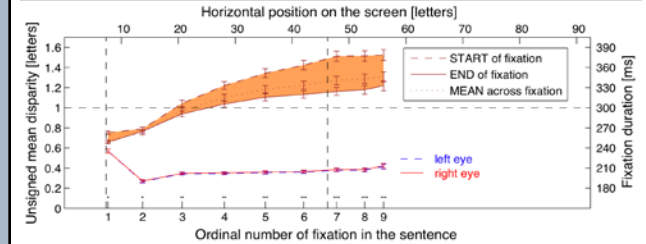


Sequence of eye disparity increase-reduction across successive saccades and fixations



- disparity *increase* from start to end of a *saccade* increases with the length of the saccade (Collewijn et al., 1995)
- disparity *reduction* from start to end of a *fixation* increases with fixation duration (cf., Liversedge et al., 2006)

Accumulation of disparity across the sentence



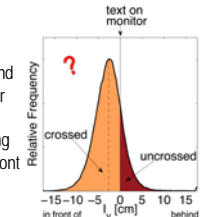
Start-of-fixation disparity data demonstrate that there is a steady accumulation of the mean unsigned fixation disparity across fixations. End-of-fixation disparities also increase across the sentence, but not as much as the start-of-fixation disparities. This implies that the net disparity reduction throughout fixation (i.e., the shaded area) increases as the eyes move from left to right through a sentence. The data pattern suggests that the visuo-oculomotor system tolerates the accumulation of fixation disparity only to a certain degree.

- dependent variable: net disparity reduction from start to end of fixation, calculated as $|D_{xStart}| - |D_{xEnd}|$

Summary and Conclusion

Analyses of horizontal and vertical fixation disparities in reading indicated that the most prevalent type of disparate fixation was crossed, while the left eye frequently fixated somewhat above the right eye. Vergence movements during fixation led to a reduced disparity at the end of fixation as compared to the start of fixation. Analyses of monocular contributions to vergence confirmed that the data pattern observed here is not an artefact. Fixation disparity accumulated during the course of successive saccades and fixations within a line of text, but only to an extent that did not compromise single binocular vision. We conclude that in reading, the version and vergence system interact in a way that is qualitatively similar to what has been observed in simple non-reading tasks.

Open question: What factors make the distribution describing the binocular fixation point I_{xy} peak at a position slightly in front of the screen of text (here) vs. behind it (Liversedge et al., 2006)?



References

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Heller, D., & Radach, R. (1999). Eye movements in reading: Are two eyes better than one? In W. Becker, H. Deubel & T. Mergner (Eds.), *Current oculomotor research. Physiological and psychological aspects* (pp. 341-348). New York: Kluwer Academic, Plenum.

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