

# Are reading tasks relevant?

## Comparing eye movements of children with and without reading disorder in silent and oral reading.

### A pilot experiment

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## Introduction

Although eye tracking has found increasing use in psycholinguistic reading research in recent decades (for overview see [1]), there is a lack of combined studies relating to the manifestation of eye movements in different reading modes with respect to reading skills and reading acquisition.

**Reading mode** (silent and oral reading, SOR) has already been investigated in competent adult reading (e.g. [2, 3]). Persons reading orally showed smaller saccade amplitudes and longer fixation durations, an increased number of regressions and an increased reading time compared to reading silently (summary in [4, 5]). A study with typical developed English-speaking children found higher numbers of fixations and longer fixation durations for oral compared with silent reading [6]. However, the transferability of these results into German-speaking readers is limited, as studies have shown that eye movement parameters differ during reading acquisition depending on orthographic consistency [7, 8].

**Reading skills** have been taken into account by numerous studies investigating eye movements of children with reading disorder (RD) and with typical reading development (TD). Summarised the data show higher numbers and enhanced durations of fixations, an increased probability of regressions and smaller amplitudes of saccades [7-13].

A **combined view** on both reading mode and reading skills is provided by only one single study on adolescents: Showing emphasised differences in eye movements in SOR than less competent adolescent readers, the authors suggest effects of reading skills on silent reading but limited on oral reading [14].

Because of the lack of combined studies about the manifestation of eye movements in SOR with respect to reading skills of children during reading acquisition in German, we address the following question: Are there statistically significant differences in total reading time and eye movement parameters between children with TD and RD depending on reading mode in fourth grade in German?

## Method

Eye Movement Recordings		Participants	
<b>Materials and Design</b>		<b>Typical reading development (TD, n = 44)</b>	
Each participant read one text orally and one text silently. SOR texts are age-appropriate, matched for length and have nearly identical orthographic frequency (see table on the right).		Reading disorder (RD, n = 9)	
<b>Apparatus</b>		<b>Statistical analysis</b>	
Tobii Remote Eyetracker T120 Data rate: 120 Hz Eye tracking technique: bright and dark pupil tracking Screen size: 17" TFT		Independent t-tests	
Gaze plot of an RD during oral reading		Gaze plot of an RD during silent reading	
Orthographic frequency (mean frequency class) [15] reading difficulty index LIX [16]		Gender & age in years	
Oral Reading: 7,96 Silent Reading: 7,82		n = 18 female, n = 26 male Mean age: 10,05 (0,41)	
Oral Reading: 34,60 Silent Reading: 34,00		n = 4 female, n = 5 male Mean age: 10,36 (0,56)	
TD		Reading skills	
Oral reading		Mean T-Score: 48,57 (5,17)	
Silent reading		Decoding (SLRT-II [17]) & Comprehension (ELFE 1-6 [18])	
RD		Mean T-Score: 37,19 (1,43)	
Oral reading		Decoding (SLRT-II [17]) & Comprehension (ELFE 1-6 [18])	
Silent reading		Mean T-Score: 55,52 (5,17)	
		Cognitive abilities	
		Mean T-Score: 52,86 (10,06) (n = 2 missing) Nonverbal CFT1-R [19]	

## Results

Comparison between SOR (see figures)		Comparison between reading skills (see tables)	
Depending on SOR within the groups, the results show statistically and practically significant differences between SOR for TD in the majority of parameters ( $p < .05$ , $d > .2$ ) with the exception of regressive saccade amplitudes and number of regressive intra-word saccades ( $p > .05$ ). In contrast, RD showed only differences in SOR in restricted number of eye movement parameters. Differences were found in reading duration as well as number of progressive and regressive inter-word saccades. Other parameters showed no differences in eye movements in both tasks in RD ( $p > .05$ ), but in all of these parameters effect size indicated a practically significant difference ( $d > .2$ ).		Depending on reading skills, the comparisons in SOR between TD and RD showed statistically and practically significant differences in some parameters ( $p < .05$ , $d > .2$ ). In oral reading, there was no difference in fixation duration ( $p > .05$ ) but in number of fixations ( $p < .05$ ). In addition, differences in amplitudes and number of progressive intra- and inter-word saccades were found ( $p < .05$ ). In contrast, in silent reading, the comparison only showed differences in number of fixations, fixation duration as well as number of progressive and regressive intra-word saccades ( $p < .05$ ). In addition, regressive saccade amplitudes and number of regressive inter-word saccades showed no differences in SOR ( $p > .05$ ).	
<b>Text reading duration</b>		<b>Progressive saccades</b>	
TD: $p < .001^{***}$ , $d = 1.024$		intra-word: $p = .05^*$ , $d = .320$	
RD: $p = .043^*$ , $d = .872$		inter-word: $p = .134^{ns}$ , $d = .921$	
<b>Number of fixations</b>		TD: $p < .001^{***}$ , $d = .630$	
TD: $p = .004^{**}$ , $d = .471$		RD: $p = .003^{**}$ , $d = 1.736$	
RD: $p = .302^{ns}$ , $d = .377$		TD: $p = .002^{**}$ , $d = .539$	
<b>Mean duration of fixations</b>		RD: $p = .235^{ns}$ , $d = .775$	
TD: $p < .001^{***}$ , $d = 1.220$		intra-word: $p = .891^{ns}$ , $d = .049$	
RD: $p = .565^{ns}$ , $d = .240$		inter-word: $p < .001^{***}$ , $d = 1.418$	
		TD: $p = .675^{ns}$ , $d = .060$	
		RD: $p = .679^{ns}$ , $d = .142$	
		TD: $p = .656^{ns}$ , $d = .066$	
		RD: $p = .763^{ns}$ , $d = .104$	

Parameter	TD (n = 44)	RD (n = 9)	t-statistics and effect size
<b>Oral Reading</b>			
Text reading duration	70,27 (17,21)	101,22 (24,69)	3,59 9,65 .005 1,665
<b>Fixations</b>			
Number of fixations	185,39 (26,58)	239,22 (41,23)	3,76 9,41 .004 1,833
Mean duration of fixations	339,72 (60,98)	379,67 (37,44)	1,89 51 .065 .690
<b>Progressive saccades</b>			
Intra-word: number	38,00 (13,25)	64,78 (18,53)	5,15 51 .000 1,885
Intra-word: amplitude	3,64 (0,42)	3,33 (0,26)	2,11 51 .040 .777
Inter-word: number	89,36 (9,36)	97,56 (7,28)	2,47 51 .017 .905
Inter-word: amplitude	5,70 (0,68)	5,12 (0,59)	2,37 51 .022 .870
<b>Regressive saccades</b>			
Intra-word: number	14,25 (5,60)	26,78 (11,20)	3,27 8,833 .010 1,845
Intra-word: amplitude	3,28 (0,47)	3,13 (0,39)	0,89 51 .380 .327
Inter-word: number	23,93 (7,48)	29,56 (10,64)	1,51 9,679 .163 .699
Inter-word: amplitude	5,75 (1,08)	5,96 (1,41)	0,51 51 .613 .185

Parameter	TD (n = 44)	RD (n = 9)	t-statistics and effect size
<b>Silent Reading</b>			
Text reading duration	59,25 (16,98)	95,33 (27,78)	3,76 9,26 .004 1,891
<b>Fixations</b>			
Number of fixations	171,84 (33,17)	232,00 (45,94)	4,66 51 .000 1,696
Mean duration of fixations	309,76 (61,05)	372,01 (61,15)	2,79 51 .007 1,019
<b>Progressive saccades</b>			
Intra-word: number	40,68 (16,24)	69,11 (24,84)	3,29 9,45 .009 1,591
Intra-word: amplitude	3,89 (0,39)	3,62 (0,39)	1,87 51 .067 .692
Inter-word: number	83,07 (10,53)	90,22 (7,51)	1,93 51 .059 .707
Inter-word: amplitude	5,94 (0,84)	5,34 (1,02)	1,90 51 .064 .689
<b>Regressive saccades</b>			
Intra-word: number	12,95 (5,87)	26,33 (13,86)	2,85 8,60 .020 1,739
Intra-word: amplitude	3,24 (0,45)	3,18 (0,45)	0,34 51 .738 .133
Inter-word: number	15,95 (7,32)	19,44 (9,40)	1,24 51 .220 .454
Inter-word: amplitude	5,66 (1,14)	5,77 (1,47)	0,27 51 .792 .092

## Discussion

**Results.** To the best of our knowledge, this study is one of the first to investigate SOR and eye movements in children, i.e. individuals in reading acquisition, with and without reading disorder. The results of TD indicate different characteristics of eye movement parameters depending on reading mode, corresponding with a study of adolescents in German [14]. In contrast, the data of RD show only isolated differences. This discrepancy between TD and RD in eye movements, except regressions, could indicate an adaptation of TD to demands of reading strategies as a function of reading mode, but this is not similarly performed by RD. Differences depending on reading skills, i.e. comparing TD and RD, are more distinct in oral than in silent reading.

**Limitations.** It has to be taken into account that even with cautious construction of extensively matched texts, these could contain different linguistic requirements and therefore qualitative differences may arise [6, 14]. Therefore, the knowledge gained in this pilot experiment needs further examination and differentiation. The long-term study BLab (see QR-Code) at the Humboldt-Universität zu Berlin represents a suitable basis for this due to its sample size.

**Practical relevance.** In the diagnosis of decoding ability during reading acquisition, analysis of oral reading dominates [20]. The results reported here point out to the differences in eye movements between SOR and between TD and RD, indicating differences in adaptation of reading strategies. Reading instruction and intervention should target abilities in both reading modes and carefully facilitate the transition from oral to silent reading to support RD.

## References

[1] Blythe, H. I. & Joseph, H. S. S. L. (2011). Children's eye movements during reading. In S. P. Livens & I. Gilchrist & S. Everling (Eds.), *The Oxford Handbook of Eye Movements* (1-41). Oxford: Oxford University Press.

[2] Ashby, J., Yang, J., Evans, K. H. C. & Rayner, K. (2012). Eye movements and the perceptual span in silent and oral reading. *Attention, Perception, and Psychophysics*, 74(4), 634-640.

[3] Inhoff, A. W. & Radach, R. (2014). Parafoveal preview benefits during silent and oral reading: Testing the parafoveal information extraction hypothesis. *Visual Cognition*, 22(3-4), 354-376.

[4] 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), 1457-1506.

[5] Schotter, E. R. & Rayner, K. (2014). The Work of the Eyes During Reading. In A. Pollatsek & R. Treiman (Eds.), *The Oxford Handbook of Reading* (1-25). Oxford University Press.

[6] Vorstius, C., Radach, R. & Lomigan, C. J. (2014). Eye movements in developing readers: A comparison of silent and oral sentence reading. *Visual Cognition*, 22(3), 458-485.

[7] Hutzler, F. & Wimmer, H. (2004). Eye movements of dyslexic children when reading in a regular orthography. *Brain and Language*, 89(1), 235-242.

[8] Dürrwächter, U., Sokolov, A. N., Reinhard, J., Klosinski, G. & Trauzettel-Klosinski, S. (2010). Word length and word frequency affect eye movements in dyslexic children reading in a regular (German) orthography. *Annals of Dyslexia*, 60(1), 86-101.

[9] De Luca, M., Di Pace, E., Judica, A., Spinelli, D. & Zoccolotti, P. (1999). Eye movement patterns in linguistic and non-linguistic tasks in developmental surface dyslexia. *Neuropsychologia*, 37(12), 1407-1420.

[10] De Luca, M., Borrelli, M., Judica, A., Spinelli, D. & Zoccolotti, P. (2002). Reading Words and Pseudowords: An Eye Movement Study of Developmental Dyslexia. *Brain and Language*, 80(3), 617-626.

[11] Hawelka, S., Gagl, B. & Wimmer, H. (2010). A dual-route perspective on eye movements of dyslexic readers. *Cognition*, 115(3), 367-379.

[12] Mackeben, M., Trauzettel-Klosinski, S., Reinhard, J., Dürrwächter, U., Adler, M. & Klosinski, G. (2004). Eye movement control during single-word reading in dyslexics. *Journal of Vision*, 4, 388-402.

[13] Trauzettel-Klosinski, S., Koitzsch, A. M., Dürrwächter, U., Sokolov, A. N., Reinhard, J. & Klosinski, G. (2010). Eye movements in German-speaking children with and without dyslexia when reading aloud. *Acta Ophthalmologica*, 88(6), 681-691.

[14] Krieber, M., Bartl-Pokorny, K. D., Pokorny, F. B., Zhang, D., Landerl, K., Körner, C., ... Marschik, P. B. (2017). Eye Movements during Silent and Oral Reading in a Regular Orthography: Basic Characteristics and Correlations with Childhood Cognitive Abilities and Adolescent Reading Skills. *PLOS ONE*, 12(2), e0170986.

[15] Goldhahn, D., Eckart, T. & Quasthoff, U. (2012). Building Large Monolingual Dictionaries at the Leipzig Corpora Collection: From 100 to 200 Languages. In *Proceedings of the 8th International Language Resources and Evaluation (LREC'12)*.

[16] Björnsson, C. H. (1968). *Läsbarhet*. Stockholm: Liber.

[17] Moll, K. & Landerl, K. (2014). *SLRT-II - Les- und Rechtschreibtest* (2nd ed.). Göttingen: Hogrefe.

[18] Lenhard, W. & Schneider, W. (2006). *Eine Leseverständnis für Erst- bis Sechstklässler (ELFE 1-6)*. Göttingen: Hogrefe.

[19] Weiß, R. H. & Osterland, J. (2012). *CFT 1-R - Grundintelligenztest Skala 1 - Revision* (1st ed.). Göttingen: Hogrefe.

[20] Kragler, S. (1995). The transition from oral to silent reading. *Reading Psychology: An International Quarterly*, 16(4), 395-408.

