

COGNITIVE DEMAND IN THE DEM TEST FROM THE PERSPECTIVE OF FIXATION DURATION ANALYSIS

**Evita Serpa, Elizabete Ozola, Madara Alecka, Asnate Berzina, Viktorija Goliskina,
Evita Kassaliete, Anete Klavinska, Marija Koleda, Rita Mikelsone, Tomass Ruza,
Aiga Svede, Daniela Toloka, Sofija Vasiljeva, Liva Volberga, Ilze Ceple,
& Gunta Krumina**

*University of Latvia, Faculty of Physics, Mathematics and Optometry,
Department of Optometry and Vision Science, Riga (Latvia)*

Abstract

Introduction: The Developmental eye movement (DEM) test is a widely applied method for assessing eye movements under reading-like conditions. Eye-tracking studies have demonstrated a correlation between the performance of the DEM C test and the average fixation duration (Moiroud et al., 2018) and children with better reading abilities have significantly shorter average fixation duration in the DEM test compared to children with poorer reading abilities (Hindmarsh et al., 2021). Webber et al. (2011) demonstrated that the horizontal task performance time correlates with the average fixation duration in reading, however, the correlation between average fixation duration in the DEM test and reading task performance were not analyzed. Since the performance of the horizontal DEM test requires similar visual processing and cognitive demands as in reading (Ayton et al., 2009), and one of the factors that characterizes cognitive demand is fixation duration (Reney et al., 2014), the aim of the current study is to explore the relation between DEM test performance and eye movement parameters in reading text in children with and without reading difficulties.

Methods: The DEM test and age-appropriate reading text were demonstrated on a computer screen at 65 cm distance and eye movement recording was performed with Tobii Pro Fusion (250 Hz) eye tracker. The average fixation duration from 57 school-aged children in fourth grade (9-11 years old; average age 10) was analyzed. Children's reading skills were assessed using the Acadience Reading test.

Results: The average fixation duration in the DEM test was significantly shorter compared to the average fixation duration in the reading task ($p < .001$). A high correlation was observed between the participants' average fixation duration in the DEM test and the average fixation duration in reading task ($r = .349$, $p = .008$). A high correlation was also observed between the average fixation during reading and the Acadience Reading test composite score ($r = .698$, $p < .001$).

Conclusions: The results demonstrate that the average fixation duration in the DEM test is shorter than during reading, leading to the conclusion that the cognitive demand in the DEM test may be lower than during reading. However, the average fixation duration during reading correlates more strongly with reading ability than the average fixation duration in the DEM test.

Keywords: *Children, cognitive demand, DEM test, fixation duration, reading.*

1. Introduction

Reading is a complex learned skill that requires coordination of many cognitive processes, including visual perception and oculomotor skills. During reading, saccades of varying amplitude are made, separated by fixations during which visual information is perceived (Rayner, 1986). Eye-tracking studies have shown that as children's reading skills develop, the amplitude of reading-directed saccades increases, and the average fixation duration decreases (Stranberg, 2019), but children with reading difficulties have more fixations, and their fixation durations are longer (Lefton et al., 1979). Fixation duration is one of the factors that characterizes cognitive demand in reading-related tasks (Reney et al., 2014) and in natural scenes (Walter & Bex, 2021).

The Developmental eye movement (DEM) test is a widely applied method for assessing eye movements under reading. The results of this test have been correlated with reading skills in school-aged children (Serdjukova et al., 2017). The DEM test contains A and B tests for vertical reading, and C test for

horizontal reading. The horizontal DEM test requires similar visual processing and cognitive demands as reading (Ayton et al., 2009). Eye-tracking studies have shown that there is a correlation between the performance of the DEM C test and the average fixation duration (Moiroud et al., 2018), as well as a correlation between the horizontal task performance time and mean fixation duration during reading (Webber et al., 2011).

The aim of the current study is to explore the relation between DEM test performance and eye movement parameters during reading in children with and without reading difficulties.

2. Methods

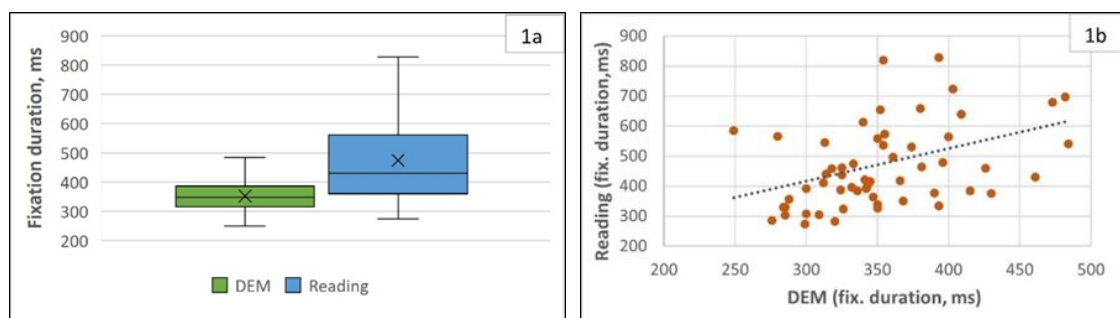
Participants in this study were 57 school-aged children from fourth grade, aged 9-11 years with an average age of 10. All participants had normal vision. The DEM test and age-appropriate reading text were demonstrated on a computer screen at 65 cm. A modified version of the DEM C test containing 40 digits was used. The experiment started with the DEM C test, followed by a reading task in which participants read aloud a short age-appropriate text consisting of 24 words. Eye movements were recorded using Tobii Pro Fusion (250 Hz) eye tracker and Titta Master toolbox (Niehorster et al., 2020) during the DEM test and reading task. The I2MC algorithm (Hessels et al., 2017) was used to detect fixation duration, which was the eye movements parameter analyzed in this study. Participants' reading skills were assessed using Acadience Reading test, and the composite score was used for analysis, where higher composite score indicated better reading ability. Data analysis was using SPSS 22.0 (SPSS Inc., Chicago, IL, USA).

3. Results

The average fixation duration during the DEM test ($M = 353$ ms, $SD = 53$) was compared to that during the reading task ($M = 472$ ms, $SD = 163$), and a significant difference was found, $t(56) = -6.01$, $p < .001$ (Figure 1a). Specially, the average fixation duration during the DEM test was significantly shorter than that during the reading task.

The results of the correlation analysis demonstrate a relationship between the participants' average fixation duration in the DEM test and the average fixation duration in the reading task ($r = .349$, $n = 57$, $p = .008$) (Figure 1b). A high correlation was observed between the average fixation duration during reading and the Acadience Reading test composite score ($r = .698$, $n = 57$, $p < .001$), but the correlation between the composite score and the average fixation duration in the DEM test was weak ($r = .141$, $n = 57$, $p < .295$).

Figure 1a.- Fixation duration in the DEM test and during reading;
1b - a correlation between the fixation duration in the DEM test and during reading.



4. Discussion

One of the most significant findings of this study is that the average fixation duration in the DEM test is significantly shorter than during reading. This is a novel result, as previous studies have not directly compared fixation duration between these two tasks. The correlation between fixation durations in the two tasks suggests that longer fixations in the DEM test may also indicate longer fixations during reading, which is a characteristic of poorer reading skills in children (Lefton et al., 1979; Spichtig et al., 2017). The results of this study are consistent with previous findings, as the average fixation duration during reading strongly correlates with the Acadience Reading test composite score, which is a measure of reading skills.

Zegermann et al. (2016) have suggested that cognitive demand influences the duration of fixation, with higher demand leading to longer fixations. Fixation duration is also a factor that characterizes cognitive demand in reading-related tasks (Reney et al., 2014). As the DEM test is performed under reading-like

conditions, fixation duration could be a factor for comparing cognitive demand between the DEM test and reading. The shorter fixation duration in the DEM test than during reading suggests that cognitive demand in the DEM test may be lower than during reading.

Since children's reading eye movements evolve with development of their reading skills, it would be valuable to conduct further research analyzing the relationship between fixation duration in the DEM test and during reading in other age groups of children.

Acknowledgements

We thank schools – Marupes State Gymnasium, Marupes Elementary School, Rigas Cultures Secondary School, Kuldigas Center Secondary School – for cooperation. This study was supported by the LCS Project No. lzp-2021/1-219, the UL Project No. Y5-AZ77, and the UL Foundation Project No. 2260.

References

- Ayton, L. N., Abel, L. A., Fricke, T. R., & McBrien, N. A. (2009). Developmental eye movement test: what is it really measuring? *Optometry and Vision Science*, 86(6), 722–730.
- Hessels, R. S., Niehorster, D. C., Kemner, C., & Hooge, I. T. C. (2017). Noise-robust fixation detection in eye movement data: Identification by two-means clustering (I2MC). *Behavior Research Methods*, 49(5), 1802–1823.
- Hindmarsh, G. P., Black, A. A., White, S. L., Hopkins, S., & Wood, J. M. (2021). Eye movement patterns and reading ability in children. *Ophthalmic and Physiological Optics*, 41(5), 1134–1143.
- Lefton, L.A., Nagle, R.J., Johnson, G. & Fisher, D.F. (1979). Eye movement dynamics of good and poor readers: then and now. *Journal of Reading Behavior*; 11, 319–328.
- Moiroud, L., Gerard, C. L., Peyre, H., & Bucci, M. P. (2018). Developmental Eye Movement test and dyslexic children: A pilot study with eye movement recordings. *PloS One*, 13(9), e0200907. <https://doi.org/10.1371/journal.pone.0200907>
- Niehorster, D. C., Andersson, R., & Nyström, M. (2020). Titta: A toolbox for creating PsychToolbox and Psychopy experiments with Tobii eye trackers. *Behavior Research Methods*, 52(5), 1970–1979.
- Raney, G. E., Campbell, S. J., & Bovee, J. C. (2014). Using eye movements to evaluate the cognitive processes involved in text comprehension. *Journal of Visualized Experiments: JoVE*, (83), e50780. <https://doi.org/10.3791/50780>
- Rayner, K. (1986). Eye movements and the perceptual span in beginning and skilled readers, *Journal of Experimental Child Psychology*, 41(2), 211-236.
- Serdjukova, J., Ekimane, L., Valeinis, J., Skilters, J. & Krumina, G. (2017). How strong and weak readers perform on the Developmental Eye Movement test (DEM): norms for Latvian school-aged children. *Reading and Writing: An Interdisciplinary Journal*, 30(2), 233–252.
- Spichtig, A. N., Pascoe, J. P., Ferrara, J. D., & Vorstius, C. (2017). A Comparison of Eye Movement Measures across Reading Efficiency Quartile Groups in Elementary, Middle, and High School Students in the U.S. *Journal of Eye Movement Research*, 10(4), 10.16910/jemr.10.4.5. <https://doi.org/10.16910/jemr.10.4.5>
- Strandberg, A. (2019). Eye movements during reading and reading assessment in Swedish school children – A new window on reading difficulties, *ETRA'19: In Proceedings of the 11th ACM Symposium on Eye Tracking Research & Applications*, 59, 1–3.
- Walter, K., & Bex, P. (2021). Cognitive load influences oculomotor behavior in natural scenes. *Scientific Reports*, 11(1), 12405. <https://doi.org/10.1038/s41598-021-91845-5>
- Webber, A., Wood, J., Gole, G., & Brown, B. (2011). DEM test, visagraph eye movement recordings, and reading ability in children. *Optometry and Vision Science*, 88(2), 295–302.
- Zagermann, J., Pfeil, U., & Reiterer, H. (2016). Measuring Cognitive Load using Eye Tracking Technology in Visual Computing. *Proceedings of the Sixth Workshop on Beyond Time and Errors on Novel Evaluation Methods for Visualization*, 78–85.