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## Agreement Processing in Dutch Adults with Dyslexia

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# **SUMMARY**



This PhD thesis investigates the processing of agreement violations in Dutch adults with dyslexia when reading or listening to sentences, and compares their performance to that of Dutch adults without dyslexia. In particular, we focused on the processing of gender and number (dis)agreement using event-related potentials (ERPs) and subject-verb (dis)agreement using self-paced reading (SPR). The ERP and SPR data were supplemented with behavioral measures (i.e., accuracy on the grammaticality judgement task).

**Chapter 1** begins with a general introduction, establishing the topic and providing a theoretical and methodological framework for the thesis. This chapter first provides an overview of the definitions and etiology of dyslexia, as well as the characteristics of adults with dyslexia, the population under investigation. This is followed by a description of the different theories on morphosyntactic processing in dyslexia. The subsequent sections focus on the description of the methods used in the thesis: ERPs and SPR, as well as a description of the relevant ERP components. Three major ERP components have been identified in sentence processing research: the LAN and the P600 (typically associated with morphosyntactic processing), and the N400 (traditionally related to the processing of semantics). Special emphasis was placed on studies on agreement violation processing in dyslexia that elicited these ERP components. The last part of this chapter elaborates on the linguistic background of the two types of linguistic structures under investigation: gender and number (dis)agreement and subject-verb (dis)agreement in Dutch.

After providing a theoretical and methodological basis, Chapter 1 ends with outlining the four research questions of the thesis. The first two research questions focused on the differences in performance between adults with and without dyslexia. The first question is related to the behavioral grammaticality judgement task used in all three studies in the thesis: (1) Is there a difference between adults with and without dyslexia on a behavioral grammaticality judgement task? The second research question concerns the first two experiments conducted with ERPs: (2) Does the neurophysiological pattern (as measured with ERPs) during processing of morphosyntactic information differ between adults with and without dyslexia? The last two research questions were related to the performance of adults with dyslexia. Thus, the third research question was related to the ERP experiments: (3) Is there a processing difference between reading and listening to the same stimuli for adults with dyslexia? Finally, the last research question focused on the different types of disagreement (within-phrase gender and number disagreement in the two ERP experiments and across-phrase subject-verb disagreement in the SPR experiment): (4) Is there a difference between within-phrase and across-phrase disagreement processing for adults with dyslexia?

**Chapter 2** presented an ERP listening experiment in Dutch adults with dyslexia. The first goal of the experiment in Chapter 2 was to examine the differences in the latency and the distribution of the ERP effects between adults with and without dyslexia in processing auditorily presented stimuli containing either gender or number disagreement. The results of adults with dyslexia were compared qualitatively to the behavioral and ERP results of adults without dyslexia by Popov (2017). As expected, our findings show that there is a difference in processing agreement violations between the two groups, which was reflected by the difference in latency and different ERP component characteristics between the groups. More specifically, listening to sentences containing gender disagreement elicited no ERP effect for adults with dyslexia, while a frontal negativity was found for number disagreement. The puzzling finding of a frontal negativity in response to number disagreement could be interpreted as a potential LAN-like component, reflecting violation detection, or as a compensatory mechanism used by adults with dyslexia to support their difficulties with morphosyntactic processing. For adults without dyslexia, Popov (2017) reported a LAN-P600 pattern in the gender condition, and a P600, associated with sentence reanalysis/repair, only in the number condition. The absence of an ERP effect in the gender condition for adults with dyslexia indicates that they are less sensitive to the violation in the gender condition compared to adults without dyslexia. The onset of the effect in the gender condition was also delayed in adults with dyslexia compared to adults without dyslexia. Thus, compared to adults without dyslexia, adults with dyslexia exhibit atypical processing of gender and number disagreement using ERPs. The second goal of the experiment from Chapter 2 was to compare the ERP responses to gender and number disagreement in the group of adults with dyslexia. Due to the nature of the violations and the difference in perceptual salience between the two conditions, we assumed that adults with dyslexia will have more difficulty detecting the violation in the gender compared to the number condition. The results were in line with our prediction, since no ERP effect was elicited in the gender condition, while a frontal negativity was present in the number condition for adults with dyslexia. We also expected number to be more complex to repair than gender due to the presence of multiple repair options. Our results are inconclusive regarding the structural repair mechanisms in spoken stimuli in adults with dyslexia, since no P600 was elicited in response to gender or number disagreement.

The experiment presented in **Chapter 3** was a replication of the experiment in Chapter 2 in the visual modality. The first goal was to compare the performance of adults with and without dyslexia in response to visually presented gender and number disagreement, as measured with ERPs. As predicted, our results show

group differences in processing gender and number disagreement. In the group of adults with dyslexia, sentences containing gender disagreement elicited a P600, while sentences containing number disagreement elicited a frontal negativity and a P600. Due to its latency, this unexpected finding of a frontal negativity is most likely not a ‘true’ LAN, but rather related to the recognition of the following word or late morphosyntactic integration. The results of adults with dyslexia were compared qualitatively to the behavioral and ERP results of adults without dyslexia (Popov & Bastiaanse, 2018). For adults without dyslexia, both gender and number disagreement elicited a P600 only. Both in the gender and the number condition, the onset of the ERP effect was approximately 200 ms later in the dyslexia group than in the group without dyslexia. The differences in the time course and the ERP patterns between the groups indicate that agreement violation processing in adults with dyslexia is slower and atypical compared to adults without dyslexia. The second goal of the experiment in Chapter 3 was to compare the ERP responses of adults with dyslexia to sentences containing gender disagreement and those containing number disagreement. Since we did not see differences between the elicited P600 to gender and number disagreement in adults with dyslexia, our results are inconclusive regarding the structural repair processes in dyslexia. Our final goal in Chapter 3 was to qualitatively compare the ERP results of adults with dyslexia in response to gender and number disagreement in listening (Chapter 2) and reading (Chapter 3). The results show that presentation modality plays a role in the performance of adults with dyslexia, since different ERP components were found in listening and reading for the same stimuli.

**Chapter 4** presented an SPR experiment on the processing of subject-verb disagreement in Dutch adults with and without dyslexia. Our main goal in Chapter 4 was to investigate the influence of linear distance (i.e., the number of words between the subject and the verb) as a measure of working memory (WM) load on the processing of subject-verb disagreement. We measured both accuracy on the grammaticality judgement task, as well as the reading times (RTs) in the three critical regions (i.e., the verb as the integration point, the spill-over region immediately following the verb, and the final word) for the two groups. Firstly, we compared the performance of adults with and without dyslexia on the grammaticality judgement task. As predicted, our findings show that, although both groups perform close-to-ceiling on accuracy, adults with dyslexia have an overall lower accuracy than adults without dyslexia on this task. Secondly, we investigated whether there was a difference in accuracy on the grammaticality judgement task for different levels of distance (short vs. long) and grammaticality (grammatical vs. ungrammatical) in the group of adults with dyslexia. Contrary

to our predictions, our results show that adults with dyslexia were not influenced by either linear distance or ungrammaticalities on the grammaticality judgement task. Finally, we compared the RTs of the two groups in terms of distance and grammaticality in the three critical regions. Given the common WM problems in dyslexia, we expected adults with dyslexia to show longer RTs for the three critical regions in the long-distance condition. Furthermore, assuming that adults with dyslexia do not readily notice ungrammaticalities in sentences, we predicted that adults with dyslexia will show no difference in RTs in the three critical regions. The results show that both adults with and without dyslexia display longer RTs for the integration point (i.e., verb) and the spill-over region following the verb. However, only adults with dyslexia exhibited longer RTs for the final word in the long- than in the short-distance condition, associated with syntactic integration difficulty at the end of the sentence. Therefore, an increase in linear distance between the subject and the verb leads to longer RTs in the three critical regions, rather than lower accuracy, in the group with dyslexia.

The thesis ends with **Chapter 5**, which contains the general discussion and conclusions, as well as the implications and directions for future research. In this chapter, the four main research questions are presented and discussed in relation to the findings of the three experiments. Concerning research question 1, we can confirm that there is a difference in performance between adults with and without dyslexia on the behavioral grammaticality judgement task. While both adults with and without dyslexia performed close-to-ceiling on this task, adults with dyslexia still performed more poorly than adults without dyslexia on the task in all three studies. Regarding research question 2, the results show group differences in the ERP patterns between adults with and without dyslexia in response to gender and number disagreement in both listening and reading. This indicates that adults with dyslexia process agreement violations differently than adults without dyslexia. In relation to research question 3, we found an ERP processing difference between reading and listening to the same stimuli for adults with dyslexia, which means that presentation modality plays a role in agreement violation processing in adults with dyslexia. Finally, concerning research question 4, our findings suggest that there are no large differences between the two types of disagreement. We see that adults with dyslexia exhibit slower processing of both within-phrase gender and number disagreement using ERPs and between-phrase subject-verb disagreement using SPR. Thus, both ERPs and SPR emerge as sensitive methods of examining agreement violation processing in adults with dyslexia, as well as differences in agreement violation processing between adults with and without dyslexia.





