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Agreement Processing in Dutch Adults with Dyslexia

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CHAPTER 5

General Discussion and Conclusions

5.1 Overview

The overall aim of this thesis was to investigate within-phrase gender and number (dis)agreement processing, as well as across-phrase subject-verb (dis)agreement processing in adults with dyslexia. The original plan was to investigate all of these using ERP experiments, but this could not be achieved because of the COVID-19 pandemic. Hence, for the study on subject-verb (dis)agreement, we used a self-paced-reading (SPR) paradigm. We also used behavioral grammaticality judgements in all three studies to explore whether the subtle agreement processing differences between adults with and without dyslexia could be captured by the behavioral measures, or, as previously reported (e.g., Rispens et al., 2006), only with the use of more sensitive online measures, such as ERPs (and SPR). In addition to the temporal aspects of agreement violation processing and the differences between online and offline behavior of adults with and without dyslexia, we were interested in exploring how the modality of presentation in ERP studies (listening vs. reading) influences gender and number (dis)agreement processing in adults with dyslexia. Our final goal was to compare within-phrase (gender and number disagreement) and across-phrase (subject-verb disagreement) processing in adults with dyslexia. In this chapter, we will address the research questions from the general introduction in relation to the findings from the three experiments presented in this thesis. Next, we will present the general conclusions and avenues for future research, followed by implications for remediation and accommodations.

5.2 Research Questions

5.2.1 Research Question 1: Is there a difference between adults with and without dyslexia on a behavioral grammaticality judgement task?

We saw a difference in performance between adults with and without dyslexia on the behavioral grammaticality judgement task in all three studies. Overall, both adults with and without dyslexia performed close-to-ceiling, but adults with dyslexia still performed more poorly than adults without dyslexia on these tasks. Thus, unlike in the study of Rispens et al. (2006), the difference between adults with and without dyslexia was not only visible with the use of ERPs, but also on behavioral grammaticality judgements. Additionally, these group differences were stable and visible both in listening (Chapter 2) and reading (Chapters 3 and 4), on the behavioral task that accompanied ERP measurements (Chapters 2 and 3) and SPR (Chapter 4), with different stimuli (gender and number disagreement: Chapters 2 and 3; subject-verb disagreement: Chapter 4), with a different proportion of grammaticality judgement questions (20% of the stimuli:

Chapters 2 and 3; 100% of the stimuli: Chapter 4) and under slightly different task demands (three seconds to answer the judgement question: Chapters 2 and 3; no time limit: Chapter 4). Therefore, we can conclude that differences between adults with and without dyslexia on the behavioral grammaticality judgement task are not influenced by the experimental manipulations, including modality of presentation. Our research adds to the growing body of evidence which shows that individuals with dyslexia perform more poorly than typical readers on a morphosyntactic grammaticality judgement task across the lifespan (children: Leikin & Assayag- Bouskilla, 2004; Rispens & Been, 2007; Rispens et al., 2004; adults: Cantiani et al., 2013a; Rüsseler et al., 2007; but see: children: Cantiani et al., 2015; Sabisch et al., 2006; adults: Cantiani et al., 2013a; Rispens et al., 2006; for no differences between the groups on this task).

We can conclude that the behavioral grammaticality judgement task is sensitive enough to capture general group differences between adults with and without dyslexia, with adults with dyslexia performing overall worse than adults without dyslexia. However, not all participants with dyslexia performed worse than all adults without dyslexia. Furthermore, since both groups exhibited close-to-ceiling performance, we cannot claim that these group differences are indicative of an agreement violation processing impairment in adults with dyslexia. Instead, adults with dyslexia seem to be less sensitive, rather than insensitive, than adults without dyslexia to agreement violations and inflectional morphology, similar to previous findings (Cantiani et al., 2013a, 2013b; Rispens et al., 2006; Rüsseler et al., 2007).

5.2.2 Research Question 2: Does the neurophysiological pattern (as measured with ERPs) during processing of morphosyntactic information differ between adults with and without dyslexia?

We found differences in the ERP patterns between adults with and without dyslexia in response to gender and number disagreement in both the auditory and the visual modality. In listening, there were qualitative differences between the two groups, whereas temporal and topographic differences between the groups emerged in reading. More specifically, in listening, there was no ERP effect present for gender disagreement for adults with dyslexia, whereas a frontal negativity was elicited in response to number disagreement. For adults without dyslexia, listening to sentences containing gender disagreement elicited a LAN and a P600, while number disagreement elicited only a P600 (Popov, 2017). For adults with dyslexia, reading sentences containing gender disagreement elicited a P600, while sentences with number disagreement elicited a frontal negativity and a P600. A P600 was elicited for both gender and number disagreement for

adults without dyslexia in the visual modality (Popov & Bastiaanse, 2018). Although the results of our listening study on adults with dyslexia should be interpreted with caution due to a small sample size, we nevertheless saw differences between the two groups regardless of the modality of presentation. We can thus conclude that adults with dyslexia process agreement violations using ERPs differently from adults without dyslexia. These results confirm previous reports of ERP differences between adults with and without dyslexia in response to subject-verb agreement violations (Cantiani et al., 2013a, 2013b; Rispens et al., 2006). Therefore, ERPs emerged as a sensitive measure of agreement violation processing differences between adults with and without dyslexia.

However, unlike previous studies (e.g., Cantiani et al., 2013a, 2013b), we do not claim that the atypical processing of agreement violations exhibited by adults with dyslexia should necessarily be classified as a morphosyntactic processing impairment in dyslexia. In both reading and listening, we saw that adults with dyslexia typically notice the violation (exhibited by the P600 in reading and a frontal negativity in listening). The absence of an ERP effect for adults with dyslexia in response to gender disagreement in listening could be due to ERP effects in listening being smaller than in reading and the smaller sample size of our participant group. Thus, adults with dyslexia seem to be less sensitive to agreement violations than adults without dyslexia, and if they notice them, they do so with a delay. Our behavioral and ERP results suggest that adults with dyslexia do not only exhibit slower speed of processing, but also more shallow processing of agreement violations than adults without dyslexia. This is in line with the *good-enough parsing* account (Ferreira et al., 2002; Ferreira & Patson, 2007), according to which individuals accept an incomplete (i.e., ‘good-enough’) sentence representation instead of re-analyzing the sentence in order to build a complete and thorough sentence representation when encountering a violation.

The question that remains is what causes the atypical processing of agreement violations in adults with dyslexia. Coming back to the theories of morphosyntactic processing in dyslexia, we found support for Byrne’s (1981) idea that individuals with dyslexia exhibit a less mature or less deep level of linguistic processing. However, unlike Byrne (1981), we did not investigate phonological processing in dyslexia and we cannot claim that morphosyntactic difficulties in dyslexia are independent of an underlying phonological deficit. These group differences could be driven by specific morphosyntactic processing difficulties, an underlying phonological processing deficit, or by a general linguistic processing weakness. Thus, more research is needed to establish the exact cause(s) of

these morphosyntactic processing difficulties. Finally, our results corroborate the findings of an atypical electrophysiological pattern in adults with dyslexia compared to adults without dyslexia for other ERP components (e.g., the N400: Rüsseler, et al., 2007; the MMN: Schulte-Körne et al., 2001; N1: Van Setten et al., 2016).

5.2.3 Research Question 3: Is there a processing difference between reading and listening to the same stimuli for adults with dyslexia?

Using ERPs, we found that the modality of presentation did play a role in agreement violation processing in adults with dyslexia. More specifically, we found that they showed a delayed P600 in reading in response to both gender and number agreement violations, as well as a late frontal negativity for number agreement violations (Chapter 3). In contrast, in listening, no ERP effect was elicited for gender agreement violations, while a LAN-like frontal negativity emerged in response to number violations (Chapter 2). Thus, different modalities elicited different ERP effects. However, it bears mentioning that gender and number disagreement elicited a slightly different ERP pattern for reading and listening in adults without dyslexia as well (Popov, 2017). More specifically, a LAN was present for listening in adults without dyslexia, but not in reading, while the P600 was present in both modalities (Popov, 2017). If we assume that reading and listening rely on the same processing mechanism, then identical components should be elicited in both modalities (Friederici et al., 1993; but see: Hagoort & Brown, 2000, who elicited the LAN in almost all conditions in listening, but not in reading the same stimuli). Therefore, it is possible that reading and listening do not entail exactly the same processes in either typical readers or adults with dyslexia. Another possibility is that the LAN is influenced by the timing difference between reading and listening (Popov, 2017), which can explain why a LAN-like component (i.e., frontal negativity) was elicited in response to both number disagreement in listening (700-900 ms time window) and reading (800-1000 ms time window), for adults with dyslexia. Our results do not enable us to conclude whether one modality is easier than the other for adults with dyslexia, since the results of the listening study have limited generalizability and need to be interpreted with caution due to a small sample size. However, the finding of a P600 in response to written agreement violations indicates that reading as the presentation modality was not more impaired than listening in our sample of adults with dyslexia. This result has important theoretical and methodological implications for future ERP studies on adults with dyslexia, which will be discussed in more detail in Section 5.3. below.

5.2.4 Research Question 4: Is there a difference between within-phrase and across-phrase disagreement processing for adults with dyslexia?

In our ERP experiments, we observed that adults with dyslexia exhibit slower processing of within-phrase disagreement (i.e., article-noun and adjective-noun disagreement), as exhibited by a delay in the onset or longer duration of the ERP components in adults with dyslexia. In the SPR experiment, we also saw that adults with dyslexia process subject-verb disagreement across-phrase slower than adults without dyslexia in terms of reading times (RTs). In the ERP experiments, we measured at the critical word (noun), while in the SPR experiment we recorded RTs for the critical word (the verb) and the two regions following it (spill-over and the final word). Although we cannot directly compare our within-phrase ERP and across-phrase SPR results due to different methodologies used, it appears that there are no large differences between within-phrase and across-phrase disagreement processing for adults with dyslexia. However, it might be that disagreement processing is influenced more by the methodology used. For instance, SPR data revealed some interesting processes when encountering agreement violations used by adults with dyslexia, which were not visible using ERPs in our other experiments. More specifically, adults with dyslexia required more time to read the verb in sentences in the short- than in the long-distance condition during subject-verb (dis)agreement processing. Furthermore, adults with dyslexia took longer to read the final word in the short- than the long-distance disagreement condition – a finding that was not present for adults without dyslexia. This result suggests that adults with dyslexia require more time for morphosyntactic integration at the end of the sentence, which is a region that is typically excluded from ERP experiments. Altogether, while we can tentatively conclude that agreement type does not seem to play a role in an online task, future research is needed to disentangle this question using the same methodology.

5.3 General Conclusions

Our research has theoretical and methodological implications for linguistic studies in general, and for studies on morphosyntactic agreement violation processing in dyslexia in particular. First, we showed that difficulties with morphosyntactic processing in dyslexia persist into adulthood and that speed is more affected than accuracy. These results are consistent with those of Callens et al. (2012), who reported the same for university students with dyslexia on all reading and writing tasks, with the exception of spelling.

In particular, ERPs and SPR emerged as a more sensitive measure of morphosyntactic processing in adults with dyslexia than behavioral grammaticality judgements. Overall, the studies presented in this thesis indicate

that adults with dyslexia are overall less sensitive to agreement violations than adults without dyslexia and they process them with a delay. Consequently, based on our findings, we argue that subtle morphosyntactic difficulties are present in adults with dyslexia.

Our research also has methodological implications. In the ERP reading experiment, we elicited a P600 in response to written stimuli containing gender and number disagreement, similar to the P600 reported for adults with dyslexia in auditorily presented sentences (e.g., Rispens et al., 2006). Additionally, we showed that there was a difference between reading and listening to the same stimuli in adults with dyslexia in terms of ERPs. Therefore, future studies should investigate agreement violation processing in both modalities to ascertain that the observed effects are not modality-specific. A puzzling finding of a frontal negativity for adults with dyslexia emerged in the late time windows in both of our ERP studies, indicating that the effect was not caused by the modality of presentation. While we assume that this negativity is likely related to the onset of the following word, the issue of the exact functional interpretation of this late frontal negativity deserves more attention.

Finally, all three studies revealed that the temporal aspects of agreement violation processing are affected in adults with dyslexia. Adults with dyslexia appeared not only to require more time, but also to integrate morphosyntactic information at the end of a sentence, as shown by the SPR experiment. Although accuracy on the grammaticality judgement task was high for both adults with and without dyslexia, our ERP and SPR data confirm that real-time agreement violation processing (and as a result, sentence processing) in adults with dyslexia is not typical.

5.4 Implications for Remediation and Accommodations

In addition to the theoretical and methodological implications mentioned in the previous section, our research has implications for remediation of and accommodations for dyslexia. For instance, if we see an atypical pattern of morphosyntactic processing in adults with dyslexia, then this suggests that remediation of morphosyntactic difficulties should be carried out with children with dyslexia in order to overcome linguistic processing problems later in life. However, more research is needed to ascertain the causes of morphosyntactic processing difficulties in dyslexia that need to be addressed through remediation. Moreover, in our studies, we saw a delay in agreement violation processing at the level of single words. If these subtle difficulties are found in controlled online experiments, in which only one word is presented at a time, it is likely that sentence processing in a more naturalistic environment, in which more complex

sentences and longer texts are presented, is even more problematic for adults with dyslexia (Robertson & Gallant, 2019). The issue of additional time needed for language processing is particularly relevant for accommodations provided to university students with dyslexia. Currently, university students with dyslexia in The Netherlands are typically provided with ten extra minutes for every hour of an exam, while university students in the UK are provided with up to 25% extra time for taking exams (Engelhardt, 2020). However, there are no systematic studies that quantified the exact additional time needed for adults with dyslexia and our findings on the delay in agreement violation processing in dyslexia confirm that further research in this area is needed.

5.5 Future Directions

Future research could expand on the studies described in this thesis in important ways. For instance, we did not investigate whether morphosyntactic processing difficulties in adults with dyslexia are caused by a phonological deficit. Dyslexia is a heterogenous impairment (Pennington, 2006) and a phonological deficit cannot explain all symptoms in all cases of dyslexia (Castles & Friedmann, 2014; Van Bergen et al., 2014). Thus, more studies on the causes – phonological or otherwise – of morphosyntactic processing difficulties in dyslexia are warranted. Furthermore, in all three studies in this thesis, adults with dyslexia showed almost an identical performance on the grammaticality judgement task, regardless of the different experimental manipulations. Therefore, more research is necessary to determine the extent to which cognitive, linguistic and other factors (including reading experience) influence participants' performance on this task.

Since we confirmed that a P600 is elicited in adults with dyslexia in response to written morphosyntactic agreement violations in a sentential context, future studies should explore written agreement violation processing in adults with dyslexia, not only focusing on different types of agreement, but also on other linguistic violations. In particular, more research is needed on the processes underlying the P600 (i.e., repair, reanalysis, and integration), since our research on the structural repair processes of the P600 in dyslexia was inconclusive.

The results of our ERP listening study have limited generalizability due to a small sample size of participants with dyslexia. Future studies should include a larger sample size to ascertain the differences between reading and listening as the modality of presentation in adults with dyslexia using ERPs. In particular, more research is needed on the nature of the frontal negativities that seem to be commonly elicited in individuals with dyslexia in response to agreement violations (our reading and listening ERP studies on adults with dyslexia; listening studies on children with dyslexia: Cantiani et al., 2015; Sabisch et al., 2006).

The current studies show that ERP and SPR methodologies are more sensitive than behavioral tasks in identifying group differences between individuals with and without dyslexia. Therefore, more research should be done on how these methodologies can help identify individual differences between individuals with and without dyslexia, which is particularly useful for studying the effects of reading interventions (see, e.g., Hasko et al., 2014; Kujala et al., 2001).

It is generally assumed that the adverse effect of reduced reading experience is diminished in a sample of university students with dyslexia (e.g., Raveh & Schiff, 2008; Wiseheart et al., 2009). However, we did not directly investigate reading experience and whether it influenced participants' performance in our reading studies, or on the behavioral grammaticality judgement task. Further research on this topic is needed.

In Chapter 4, we investigated the influence of linear distance as a measure of working memory (WM) load on subject-verb (dis)agreement processing in adults with dyslexia in an SPR study. Future studies could explore the influence of structural distance (number of intervening syntactic nodes) and compare the two types of distance in a single study (similar to the eye-tracking study by Liu & Wang, 2019). Following Robertson and Joanisse (2010), future studies could use comprehension questions pertaining to the material intervening between the subject and the verb, rather than end-of-sentence grammaticality judgement questions, in order to burden the participants' WM load and eliminate any possibility of participants forming a reading strategy. The influence of the modality of presentation on the performance of adults with dyslexia in self-paced tasks can also be compared by using the same stimuli presented in the self-paced reading study to a self-paced listening study. Finally, the SPR stimuli used in the current study could be adapted to different methods (e.g., eye tracking or ERPs), or used for concurrent SPR and eye tracking, or SPR and ERP study, in order to gain more information regarding different aspects of agreement violation processing in adults with dyslexia.

