Cortical tracking of spoken and written language structures in (dys)fluent readers

Document status and date:
Published: 01/01/2022

DOI:
10.26481/dis.20221004mz

Document Version:
Publisher's PDF, also known as Version of record

Appendix

Impact Paragraph

How do we learn and understand language? This is probably not only one of the most fascinating and difficult questions for scientists, but also one that each of us will be curious and amazed about at some point in our lives. One way to understand the mystery of language processing is to study its fine-grained brain mechanisms. Research has shown that our brain can align its rhythmic activity, i.e., neural oscillations, to track the hierarchical structure of speech, where smaller units (e.g., syllables) are integrated into larger ones (e.g., words) to convey increasingly complex information. Similar mechanisms seem to apply to reading; however, this topic has been investigated much less so far. Thus, the current research aimed to study how the brain oscillations align to varying units of spoken and written language (here: familiar words, artificial words, random syllables and tones), and whether such mechanism differs in individuals with developmental dyslexia. We took advantage of electroencephalography (EEG) and transcranial alternating current stimulation (tACS), which are non-invasive methods that allow us to measure and modulate brain oscillations during sensory and language processing.

We found that slow cortical oscillations (here: < 8 Hz) did not appear to influence the auditory perception of transient changes (i.e., shorter than syllable length) in simple tones. However, they contributed to the integration of single syllables to familiar and artificial words. In particular, the work presented in this thesis showed that our brain can pick up repeating patterns (here: three-syllable artificial words) in continuous speech by gradually synchronizing its slow cortical oscillations with the implicitly detected word structures. Furthermore, the integration of syllables to words triggers a shift in the network organization of slow cortical oscillations across the brain toward a more globally interconnected pattern, potentially coordinating the higher-level processing of word information. Intriguingly, adults with dyslexia showed a slower build-up of word tracking responses during the learning of artificial words, and a different global brain network organization for syllable-to-word integration compared to typical readers. We also saw that better reading skills were associated with faster learning of artificial words and less long-range connectivity in tracking familiar words. These findings indicate that dyslexic readers tend to rely more heavily on larger, familiar language units and might use additional brain areas to understand language structures. In addition, we observed spatially separated slow cortical oscillations for the processing of spoken and written syllables, whereas the processing of meaningful words exhibited largely common mechanisms independently of input modality. This implies that the existing theoretical framework and research methods on speech perception may lay the foundation for further understanding of reading comprehension.

Together, our findings highlight the plasticity and adaptability of the human brain in language learning and comprehension, and shed light on this topic from more dynamic (concerning the learning course) and more coordinated (concerning the network organization) perspectives. We also call for further research on a longer timescale to explore how local and large-scale oscillatory activities interact to modulate spoken and written language comprehension as children learn to read. Moreover, we made a step forward to bridge the research gap between the processing of spoken and written language, targeting a critical "structure building" process. This may contribute to future studies on the incremental process of natural reading. Importantly, by including dyslexic readers in our research, this dissertation extends our understanding of reading difficulties from deficient auditory (phonological) and/or visual (orthographical) processing to the learning and integration of larger, more complex language structures. This could be especially useful for recognizing and improving the dysfluent reading in individuals with (familial risk of) dyslexia. Future research could apply the learning paradigm used in Chapter 3, in combination with non-invasive brain stimulation tools (such as tACS), to help beginning and dyslexic readers learn new structures in both spoken and written languages. Such investigations may eventually give insights into the development of neuroscience-warranted tools that benefit the early detection and tailored intervention of dyslexia.

The research findings reported in this dissertation have been presented at several (inter)national scientific conferences to contribute to the scientific exchange and progress in the field. All these findings either have been or will be published in open access journals to support accessibility to the scientific community. To promote science communication and collaboration with non-Dutch speaking communities, the research has also been shared with research teams in China and the United States. This may inspire future research into cross-linguistic differences in the development of language, literacy, and bilingualism. Moreover, aspects of the current dissertation concerning dyslexia have been shared with the general public in the Netherlands via local[1] and social[2] media, and on the website of our research group[3].

---

[1] Universiteit van Nederland, https://www.universiteitvannederland.nl/college/hoe-ontstaat-dyslexie

[2] Facebook page "Brain & Language Maastricht", https://www.facebook.com/BrainLanguageMaastricht

[3] M-BIC Brain and Language group, https://mbic-languagelab.nl/en/