EasyChair Preprint

№ 6512

Mapping the Arcuate Fasciculus with nTMS and Action Naming: the Effect of Transitivity

Effrosyni Ntemou, Thomas Picht, Klara Reisch, Roel Jonkers, Frank Burchert and Adrià Rofes

August 31, 2021

Abstract Academy of Aphasia 2021

Mapping the arcuate fasciculus with nTMS and action naming: the effect of transitivity

Effrosyni Ntemou[a,b*], Thomas Picht[c,d], Klara Reisch[c], Roel Jonkers[b], Frank Burchert[e], & Adrià Rofes[b]

[a] International Doctorate for Approaches to Language and Brain (IDEALAB), University of Groningen (NL), University of Potsdam (DE), Newcastle University (UK), Macquarie University (AU)

[b] Centre for Language and Cognition Groningen (CLCG), University of Groningen, Groningen, The Netherlands

[c] Department of Neurosurgery, Charité – Universitätsmedizin Berlin, Berlin, Germany

[d] Cluster of Excellence: "Matters of Activity. Image Space Material", Humboldt University, Berlin, Germany

[e] Department of Linguistics, University of Potsdam, Potsdam, Germany

[*] corresponding author, e.ntemou@rug.nl

Introduction

Language mapping with navigated Transcranial Magnetic Stimulation (nTMS) is a non-invasive method used to causally identify cortical areas involved in language processing (Hauck et al., 2015; Ille et al., 2016; Krieg et al., 2017; Picht et al., 2013; Tarapore et al., 2013). The combination of diffusion Magnetic Resonance Imaging (dMRI) and nTMS promises to increase language mapping accuracy by allowing researchers to stimulate cortical terminations of white matter tracts (Reisch et al., in prep). The arcuate fasciculus (AF) is an associative tract with cortical terminations in the frontal, parietal and temporal lobes (Bernard et al., 2019; Catani et al., 2005; Catani & Mesulam, 2008; de Weijer et al., 2015). Cortical regions connected by the AF have been shown to be differentially involved in the processing of transitive and unergative verbs, with transitive verb processing eliciting higher BOLD activation bilaterally (den Ouden et al., 2009; Shetreet et al., 2007; Thompson et al., 2007, 2010). These findings have led authors to suggest that bilateral parietal areas and left temporal areas are involved in argument structure information retrieval and verb/argument integration respectively (Meltzer-Asscher et al., 2015; Thompson & Meltzer-Asscher, 2014; cf. Matchin et al., 2019).

Methods

In the present study, we combined dMRI and nTMS during an action naming task with finite verbs (Ohlerth et al., 2020) to investigate the neural underpinnings of transitive and unergative verbs. After performing fiber tracking of the left and right AF (Fekonja et al., 2019), we identified and stimulated frontal, parietal, and temporal cortical terminations in ~10 adult native speakers of German, according to common protocols for nTMS language mapping (see Figure 1a, Krieg et al., 2017). Based on previous findings from fMRI studies, we predicted that if verb production is influenced by the number of arguments, nTMS will induce more errors during naming of transitive compared to unergative verbs.

Results

Induced errors were quantified and analysed according to cortical terminations (frontal, temporal, parietal) and verb type (transitive/unergative). For the left AF, preliminary results suggest that nTMS induced more errors with transitive verbs compared to unergative verbs when stimulating temporal terminations (see Figure 1b). Error rates between the two verb types did not differ during the stimulation of left frontal and parietal terminations. Moreover, no significant differences between transitive and unergative verbs were found during stimulation of the cortical terminations of the right AF.

Conclusions

Preliminary data suggest that suppression of posterior temporal regions leads to increased error rates during the production of transitive verbs in a sentence context. Given the inhibitory nature of our nTMS protocol, we show that posterior temporal regions are causally involved in argument structure processing. In line with previous work (den Ouden et al., 2009; Malyutina & den Ouden, 2017; Matchin et al., 2019; Thompson et al., 2010), we suggest that during action naming posterior temporal regions are necessary for argument structure processing. The present study emphasizes the importance of including verbs with different numbers of arguments during language mapping with nTMS, especially during presurgical mapping of individuals with brain tumors.

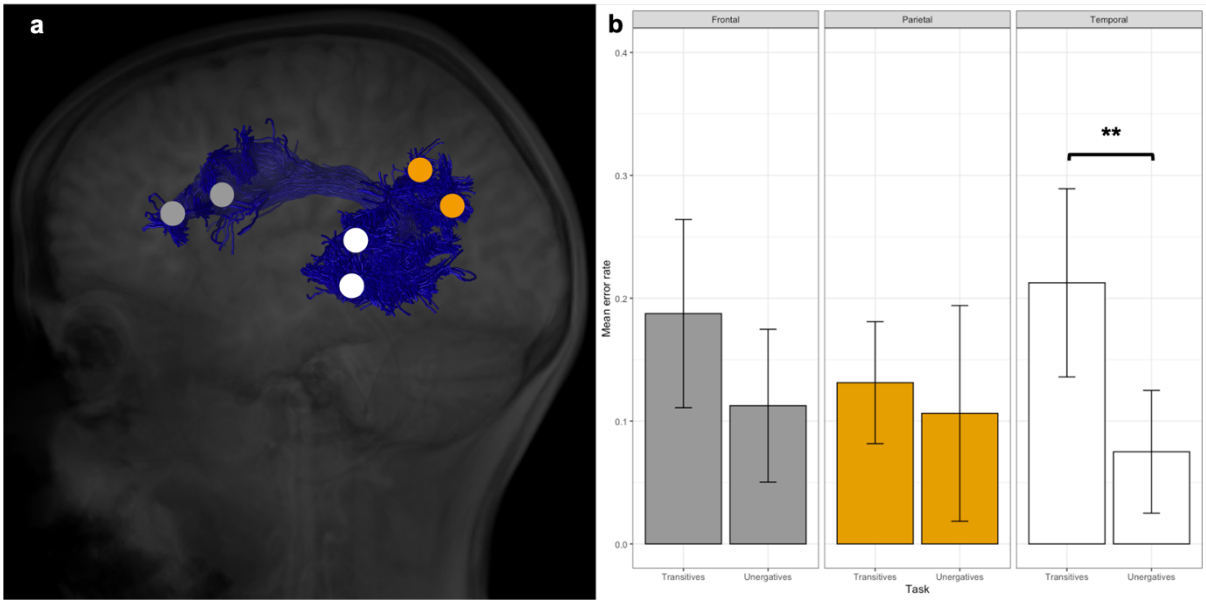

Figure 1: Visualization of stimulated cortical terminations of the left arcuate fasciculus (a) and boxplots of mean error rates according to cortical terminations and verb type (b). **: p < .01

References

Bernard, F., Zemmoura, I., Ter Minassian, A., Lemée, J.-M., & Menei, P. (2019). Anatomical variability of the arcuate fasciculus: A systematical review. *Surgical and Radiologic Anatomy*, *41*(8), 889–900. https://doi.org/10.1007/s00276-019-02244-5

Catani, M., Jones, D. K., & ffytche, D. H. (2005). Perisylvian language networks of the human brain. *Annals of Neurology*, *57*(1), 8–16. https://doi.org/10.1002/ana.20319

Catani, M., & Mesulam, M. M. (2008). The arcuate fasciculus and the disconnection theme in language and aphasia: History and current state. *Cortex*, *44*(8), 953–961. https://doi.org/10.1016/j.cortex.2008.04.002

de Weijer, A. D., Sommer, I. E. C., & Neggers, S. F. W. (2015). Functional connectivity along the arcuate fasciculus investigated with concurrent TMS-fMRI. *Brain Stimulation*, *8*(2), 381. https://doi.org/10.1016/j.brs.2015.01.219

den Ouden, D.-B., Fix, S., Parrish, T. B., & Thompson, C. K. (2009). Argument structure effects in action verb naming in static and dynamic conditions. *Journal of Neurolinguistics*, *22*(2), 196–215. https://doi.org/10.1016/j.jneuroling.2008.10.004

Fekonja, L., Wang, Z., Bährend, I., Rosenstock, T., Rösler, J., Wallmeroth, L., Vajkoczy, P., & Picht, T. (2019). Manual for clinical language tractography. *Acta Neurochirurgica*, *161*(6), 1125–1137. https://doi.org/10.1007/s00701-019-03899-0

Hauck, T., Tanigawa, N., Probst, M., Wohlschlaeger, A., Ille, S., Sollmann, N., Maurer, S., Zimmer, C., Ringel, F., Meyer, B., & Krieg, S. M. (2015). Task type affects location of language-positive cortical regions by repetitive navigated transcranial magnetic stimulation mapping. *PLOS ONE*, *10*(4), e0125298. https://doi.org/10.1371/journal.pone.0125298

Ille, S., Sollmann, N., Butenschoen, V. M., Meyer, B., Ringel, F., & Krieg, S. M. (2016). Resection of highly language-eloquent brain lesions based purely on rTMS language mapping without awake surgery. *Acta Neurochirurgica*, *158*(12), 2265–2275. https://doi.org/10.1007/s00701-016-2968-0

Krieg, S. M., Lioumis, P., Mäkelä, J. P., Wilenius, J., Karhu, J., Hannula, H., Savolainen, P., Lucas, C. W., Seidel, K., Laakso, A., Islam, M., Vaalto, S., Lehtinen, H., Vitikainen, A.-M., Tarapore, P. E., & Picht, T. (2017). Protocol for motor and language mapping by navigated TMS in patients and healthy volunteers; workshop report. *Acta Neurochirurgica*, *159*(7), 1187–1195. https://doi.org/10.1007/s00701-017-3187-z

Malyutina, S., & den Ouden, D.-B. (2017). Task-dependent neural and behavioral effects of verb argument structure features. *Brain and Language*, *168*, 57–72. https://doi.org/10.1016/j.bandl.2017.01.006

Matchin, W., Liao, C.-H., Gaston, P., & Lau, E. (2019). Same words, different structures: An fMRI investigation of argument relations and the angular gyrus. *Neuropsychologia*, *125*, 116–128. https://doi.org/10.1016/j.neuropsychologia.2019.01.019

Meltzer-Asscher, A., Mack, J. E., Barbieri, E., & Thompson, C. K. (2015). How the brain processes different dimensions of argument structure complexity: Evidence from fMRI. *Brain and Language*, *142*, 65–75. https://doi.org/10.1016/j.bandl.2014.12.005

Ohlerth, A.-K., Valentin, A., Vergani, F., Ashkan, K., & Bastiaanse, R. (2020). The verb and noun test for peri-operative testing (VAN-POP): Standardized language tests for navigated transcranial magnetic stimulation and direct electrical stimulation. *Acta Neurochirurgica*, *162*(2), 397–406. https://doi.org/10.1007/s00701-019-04159-x

Picht, T., Krieg, S. M., Sollmann, N., Rösler, J., Niraula, B., Neuvonen, T., Savolainen, P., Lioumis, P., Mäkelä, J. P., Deletis, V., Meyer, B., Vajkoczy, P., & Ringel, F. (2013). A comparison of language mapping by preoperative navigated transcranial magnetic stimulation and direct cortical stimulation during awake surgery. *Neurosurgery*, *72*(5), 808–819. https://doi.org/10.1227/NEU.0b013e3182889e01

Shetreet, E., Palti, D., Friedmann, N., & Hadar, U. (2007). Cortical representation of verb processing in sentence comprehension: Number of complements, subcategorization, and thematic frames. *Cerebral Cortex*, *17*(8), 1958–1969. https://doi.org/10.1093/cercor/bhl105

Tarapore, P. E., Findlay, A. M., Honma, S. M., Mizuiri, D., Houde, J. F., Berger, M. S., & Nagarajan, S. S. (2013). Language mapping with navigated repetitive TMS: Proof of technique and validation. *NeuroImage*, *82*, 260–272. https://doi.org/10.1016/j.neuroimage.2013.05.018

Thompson, C. K., Bonakdarpour, B., Fix, S. C., Blumenfeld, H. K., Parrish, T. B., Gitelman, D. R., & Mesulam, M.-M. (2007). Neural correlates of verb argument structure processing. *Journal of Cognitive Neuroscience*, *19*(11), 1753–1767. https://doi.org/10.1162/jocn.2007.19.11.1753

Thompson, C. K., Bonakdarpour, B., & Fix, S. F. (2010). Neural mechanisms of verb argument structure processing in agrammatic aphasic and healthy age-matched listeners. *Journal of Cognitive Neuroscience*, *22*(9), 1993–2011. https://doi.org/10.1162/jocn.2009.21334

Thompson, C., & Meltzer-Asscher, A. (2014). Neurocognitive mechanisms of verb argument structure processing. In A. Bachrach, I. Roy, & L. Stockall (Eds.), *Language Faculty and Beyond* (Vol. 10, pp. 141–168). John Benjamins Publishing Company. https://doi.org/10.1075/lfab.10.07tho