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APHASIA REHABILITATION AFTER STROKE – WHY P300 BRAIN-COMPUTER INTERFACE (BCI) TRAINING MAY BE BENEFICIAL

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ABSTRACT: This paper suggests a theoretical background for the hypothesis of P300 BCI based cognitive rehabilitation training to be a successful intervention for post-stroke aphasia [1].

POST-STROKE APHASIA

Up to 30% of all stroke survivors are affected by language comprehension or language production deficits [2]. In case of Broca aphasia, lesions affect the opercular and triangular areas of the inferior frontal gyrus, the Broca language area as well as tempoparietal regions and related neuronal circuits [e.g. 3]. While language comprehension is intact, self-expression is limited or impossible. In some cases, phonemes or words can be produced, however, communication with the environment still is challenging. Traditional speech therapy, as provided by the healthcare system, includes, among others, articulation training, slowing of speech rate, prosody training, face muscle, lip and tongue control training and use of compensatory strategies [e.g. 4]. Best results for speech therapy were found for patients in the subacute phase and for patients with language comprehension as compared to language production deficits [5], which is why alternative approaches are urgently needed for this latter group. Chronic cases are numerous, as up to 50% of all patients do not fully recover [6]. Inability to communicate negatively affects relationships [7] and may even lead to depression [8].

BCI BASED POST-STROKE REHABILITATION

BCI based rehabilitation interventions were suggested as treatments for stroke survivors. This line of research was mainly focused on motor rehabilitation [e.g. 9; 10; 11; 12; 13]. Often, motor imagery based BCI interventions were used to increase neuronal plasticity of perilesional areas and clinically relevant improvements were obtained [10].

More recently, also cognitive rehabilitation after stroke was investigated by applying BCI based neurofeedback paradigms to people after stroke with cognitive impairment such as attention deficits [14] or deficits in memory functioning [15]. A BCI based rehabilitation training improving attention capacities might also be beneficial for patients diagnosed with motor aphasia as a link between attention allocation ability and language production was suggested [16].

ATTENTION AND APHASIA

In their theory, Hula and McNeil [16] suggested a link between attention and aphasia. They state parallel processing to be based on intact neuronal network functioning throughout the cortex. Disruption of the network (by e.g. stroke) might therefore lead to loss of the ability to process information simultaneously, and thus, the ability to produce language. Their idea is supported by findings in patients with motor aphasia that show successful communication in case task complexity was decreased [17]. If the ability to produce language would be lost only due to anatomical damage, task complexity reduction would not be helpful for patients with aphasia.

Interestingly, there is also an anatomical overlap between areas that are known to play a major role in language production and those that are hypothesized to be included in the generation of the P300 amplitude. While the P300 can still be detected in patients with motor aphasia [18], its amplitude is reduced [19]. Integrity of the temporoparietal junction was emphasized as a pre-requisite not only for language production but also for P300 generation. Therefore, P300 based training could support the activation of this temporoparietal region and thereby activate areas that are involved in language production.

A BCI based rehabilitation method for aphasia patients based on an auditory BCI was already suggested [20]. This approach is based on the above-mentioned assumption of a link between aphasia symptoms and attention; however, possible brain anatomical overlap was not discussed [20]. In their study, the authors presented sentences. Participants chose the correct last word to finalize presented sentences by allocating attention to one of several words that were presented. This procedure allows for closing the language loop of trying to produce a word and receiving the sensory feedback that this effort led to the intended word production. While this approach is very interesting, it requires the participant to be able to keep in mind the sentence to be finalized while choosing the last word. Further, a participant with aphasia must be able to

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understand the spoken sentence in the presented speed to decide which is the appropriate word to finalize the sentence. These issues can be adjusted to individual needs of patients and a first feasibility test in a stroke patient were successful [21]. However, when using a visual P300 BCI paradigm in which words and sentences can be spelled, the user might be more directly engaged in working with language material and train communicational skills by attempting to read the spelled words or messages.

THE VISUAL P300 SPELLING PARADIGM

The P300 signal on which the P300 speller [22] is based varies depending on the amount of attention allocated to the task at hand [23]. Therefore, it can be used as an indicator of the attention level and might be trainable with time ([1], see figure 1). Additionally, language can be produced by using the spelling paradigm, which might support neuronal plasticity of perilesional sites, but also increase the motivation of participants. Psychological well-being is an indicator for rehabilitation success [24]. Kleih and colleagues found first results to be promising when training patients diagnosed with Broca aphasia. All patients could use the P300 spelling paradigm, even though individual adjustments were necessary. These individual adjustments such as supporting the patient to use the speller matrix, should only be used in the beginning to familiarize the end-user with the paradigm. In the course of the training, the end-user should be enabled to use the P300 speller as described.

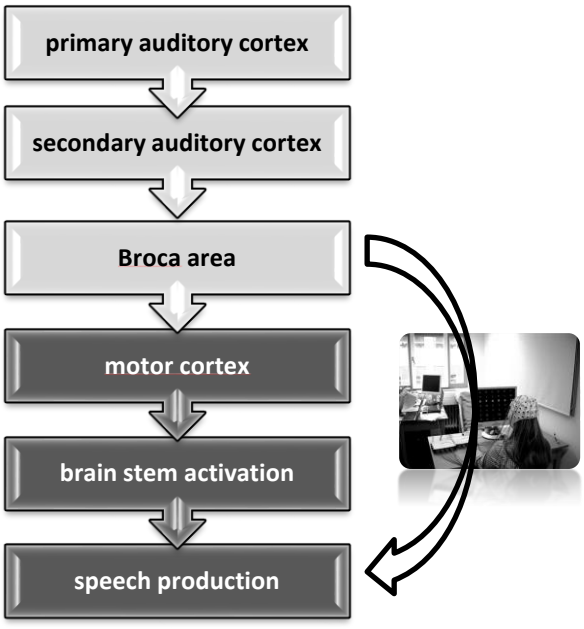

Figure 1. People with Broca aphasia can still perceive language (light grey boxes). Language production is prevented (dark grey boxes). By using a P300 BCI training, usual pathways can be circumvented while training the ability to focus attention.

INTERVENTION SPECIFICITY

Concerning aphasia subtypes, a distinction between different forms of aphasia, such as Broca, Wernicke, transcortical and anomic and according brain lesions is required for the here presented approach to be successful. An activation of brain regions involved in language production and attention allocation was hypothesized to support Broca aphasia rehabilitation after stroke. In case the lesion is not located in the described areas, only the effect of using the P300 BCI as an attention training could be investigated. As brain regions affected by a lesion might be large, overlapping and very heterogeneous between patients, it might be difficult to judge whether a patient is a possible training candidate.

CONCLUSION

P300 based BCI may support post-stroke rehabilitation in patients with aphasia. It should be further investigated how it can be best adapted to the end-user, i.e clinicians and patients alike, following the user-centred design [25]. Questions to be answered are for example: how much training is necessary? Does the increase of the P300 amplitude correlate with regaining of speech function? And, does this type of intervention yield superior results as compared to traditional speech therapy approaches which, from a technical point of view, are easier to apply? These questions are to be addressed by future research to judge the usefulness of the here presented approach.

REFERENCES

[1] Kleih SC, Gottschalt G, Teichlein E, Weilbach FX. Toward a P300 Based Brain-Computer Interface for Aphasia Rehabilitation after Stroke: Presentation of Theoretical Considerations and a Pilot Feasibility Study. Front Hum Neurosci. 2016;10(547): doi.org/10.3389/fnhum.2016.00547

[2] Flowers HL, Silver FL, Fang J, Rochon E, Martino R. The incidence, co-occurrence and predictors of dysphagia, dysarthria and aphasia after first-ever acute ischemic stroke. J Commun Disord 2013; 46: 238–248. doi: 10.1016/j.jcomdis.2013.04.001

[3] Berndt R, Caramazza A. How “regular” is sentence comprehension in Broca’s aphasia? It depends on how you select the patients. Brain Lang 1999; 67: 242–247. doi: 10.1006/brln.1999.2130

[4] Palmer R, Enderby P. Methods of speech therapy treatment for stable dysarthria: A review. Adv Speech Lang Path, 2007;9(2): 140-153.

[5] Robey RR. The efficacy of treatment for aphasic persons: a meta-analysis. Brain Lang 1994; 47: 582–608. doi: 10.1006/brln.1994.1060.

[6] Hartje, W., and Poeck, K. (2000). Klinische Neuropsychologie. Stuttgart: Georg Thieme Verlag.

[7] Visser-Meily A, Post M, Schepers V, Lindeman E.

Spouses' quality of life 1 year after stroke: Prediction at the start of clinical rehabilitation. Cerebrovasc dis, 2005;20:443-448.

[8] Gainotti G. Emotional, psychological and psychosocial problems of aphasic patients: an introduction. Aphasiology 1997;11:635–650. doi: 10.1080/02687039708249412

[9] Morone G, Pisotta I, Picchiori F, Kleih S, Paolucci S, Molinari M. Proof of principle of a brain-computer interface approach to support poststroke arm rehabilitation in hospitalized patients: design, acceptability and usability. Arch. Phys. Med. Rehabil,201596:S71–S78. doi:10.1016/j.apmr.2014.05.026

[10] Pichiorri F, Morone G, Petti M, Toppi J, Pisotta I, Molinari M, Paolucci S, Inghilleri M, Astolfi L, Cincotti F, Mattia D. Brain–computer interface boosts motor imagery practice during stroke recovery. Annals of neurology, 2015;77(5):851-65.

[11] Ang KK, Guan C. Brain-computer interface in stroke rehabilitation. J Comp Sci and Eng, 2013;7(2): 139-146.

[12] Daly J., Cheng R, Rogers J, Litinas K, Hrovat K, Dohring M. Feasibility of a new application of noninvasive brain computer interface (BCI): a case study of training for recovery of volitional motor control after stroke. J Neurol Phys Ther, 2009; 33(4):203-211.

[13] Buch E, Weber C, Cohen LG, Braun C, Dimyan M A, Ard T, Birbaumer N. Think to move: a neuromagnetic brain-computer interface (BCI) system for chronic stroke. Stroke,2008;39(3):910-917.

[14] Kleih SC, Real R, Erlbeck H, Kübler A. Treating attention deficits in chronic stroke patients using Slow Cortical Potential (SCP) Neurofeedback. In: G. Müller-Putz, J. E. Huggins & D. Steryl (Eds.). Proceedings of the Sixth International Brain-Computer Interface Meeting: BCI Past, Present, and Future, 2016; Asilomar Conference Grounds, Monterey, CA, USA, May 30- June 03., p. 211. doi:10.3217/978-3-85125-467-9-211.

[15] Kober SE, Schweiger D, Witte M, Reichert JL, Grieshofer P, Neuper C, Wood G. Specific effects of EEG based neurofeedback training on memory functions in post-stroke victims. J Neuroeng and Rehab, 2015; 12(1):107.

[16] Hula WD, McNeil M. Models of attention and dual-task performance as explanatory constructs in aphasia. Semin Speech Lang *2008;* 29:169–187. doi: 10.1055/s-0028-1082882

[17] Murray LL. Review attention and aphasia: theory, research and clinical implications. Aphasiology 1999; 13: 91–111. doi: 10.1080/026870399402226

[18] Knight RT, Scabini D. Anatomic bases of event-related potentials and their relationship to novelty detection in humans. J Clin Neurophysiol 1998;15: 3–13. doi: 10.1097/00004691-199801000-00003

[19] Hagoort P, Brown CM, Swaab TY. Lexical—semantic event-related potential effects in patients with left hemisphere lesions and aphasia and patients with right hemisphere lesions without aphasia. Brain,1996;119:627–649.doi: 10.1093/brain/119.2.627

[20] Tangermann M, Schnorr N, Musso, M. Towards Aphasia Rehabilitation with BCI (2014). In: G. Müller-Putz, G. Bauernfeind, C. Brunner, D. Steryl, S. Wriessnegger & R. Scherer (Eds.). Proceedings of the 6th International Brain-Computer Interface Conference, Technical University of Graz, Graz, Austria, Sept. 16-19.

[21] Musso, M., Bambadian, A., Denzer, S., Umarova, R, Hübner, D. & Tangermann, M. (2016). A novel BCI based rehabilitation approach for aphasia rehabilitation. In: G. Müller-Putz, J.E. Huggins, & D. Steyrl (Eds.). Proceedings of the 6th International Brain-Computer Interface Meeting: BCI Past, Present, and Future. Asilomar Conference Center, Pacific Grove, California, USA, May, 30 – June 3, p. 104.

[22] Farwell LA, Donchin E. Talking off the top of your head: toward a mental prosthesis utilizing event-related brain potentials. Electroencephalogr Clin Neurophysiol 1988;70:510–523. doi: 10.1016/0013-4694(88)90149-6

[23] Johnson R. For distinguished early career contribution to psychophysiology: award address, 1985: a triarchic model of P300 amplitude. Psychophysiology 1986;23: 367–384. doi: 10.1111/j.1469-8986.1986.tb00649.x

[24] Lyubomirsky S, King L, Diener E. The benefits of frequent positive affect: Does happiness lead to success? Psych Bull, 2005;131(6):803-855.

[25] Kübler A, Holz EM, Riccio A, Zickler C, Kaufmann T, Kleih SC et al.. The user-centered design as novel perspective for evaluating the usability of BCI-controlled applications. PLoS One 2014;9:e112392: doi: 10.1371/journal.pone.0112392