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

S.C. Kleih

1 Institute of Psychology, University of Würzburg, Würzburg, Germany
E-mail: sonja.kleih@uni-wuerzburg.de

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 tempoparietal 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 tempoparietal 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...
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
test 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 ([11], 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 patients.

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.

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.

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