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Research report

Long-term reliability of the visual EEG Poffenberger paradigm

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ABSTRACT

The Poffenberger paradigm is a simple perception task that is used to estimate the speed of information transfer between the two hemispheres, the so-called interhemispheric transfer time (IHTT). Although the original paradigm is a behavioral task, it can be combined with electroencephalography (EEG) to assess the underlying neurophysiological processes during task execution. While older studies have supported the validity of both paradigms for investigating interhemispheric interactions, their long-term reliability has not been assessed systematically before. The present study aims to fill this gap by determining both internal consistency and long-term test-retest reliability of IHTTs produced by using the two different versions of the Poffenberger paradigm in a sample of 26 healthy subjects. The results show high reliability for the EEG Poffenberger paradigm. In contrast, reliability measures for the behavioral Poffenberger paradigm were low. Hence, our results indicate that electrophysiological measures of interhemispheric transfer are more reliable than behavioral measures; the later should be used with caution in research investigating inter-individual differences of neurocognitive measures.

1. Introduction

The corpus callosum is the main connection between the two hemispheres and consists of about 200 million axons [1]. It is mainly composed of excitatory glutamatergic fibers, but can serve an inhibitory role due to GABAergic interneurons within the receiving hemisphere [2,3]. It is important for several different cognitive processes, ranging from visual perception [4,5,6,7,8] and motor activity [9,10] to higher cognitive functions such as decision-making [11], working memory [12], learning [13] and language [14]. One particularly important issue in the context of callosal research is to find reliable measurements of callosal functions. This issue is currently of special interest because of concerns about the replicability of neuroscientific and psychological studies [15]. Historically, a commonly used method to investigate the function of the corpus callosum is the classical Poffenberger paradigm [16,17]. In this task, visual stimuli (e.g. flashing white circles) are presented either in the left or the right visual half field. Participants have to react by pressing a button with either the ipsilateral or contralateral hand. Trials in which stimulus and reacting hand are on the same side are called “uncrossed”, whereas trials in which stimulus and reacting hand are on opposite sides are called “crossed”. In the uncrossed condition, neural correlates of perception and motor response are located within the same hemisphere. In the crossed condition, however, the perception is primarily located in one hemisphere while the other hemisphere accomplishes the motor output. A comparison between the reaction times (RT) of uncrossed and crossed conditions has shown that for uncrossed trials the RTs are on average 3 milliseconds (ms) faster than for crossed trials [18]. Subtracting the RTs in the uncrossed condition from the RTs in the crossed condition results in the so-called “crossed-uncrossed” difference (CUD). Since this measure is estimated by RTs and thus behavior, one can also name it behavioral CUD (bCUD). This difference measure is thought to reflect the additional processing time of the crossed condition, in which the perceptual information has to transfer from one hemisphere to the other in order to trigger the motor response. Hence, the bCUD is interpreted as an estimate for interhemispheric transfer time (IHTT), which in turn should be associated with structural properties of commissural fiber bundles. Indeed, an association between structural variability of white matter fibers and bCUD has been suggested for the corpus callosum: For example, a smaller bCUD is associated with bigger callosal size ([19]: $r = -0.50$, $p < 0.05$), as well as higher fractional anisotropy (Schulte et al., 2005: $r = -0.54$, $p < 0.05$), a measure of microstructural integrity that reflects an efficient white matter architecture [20]. Nevertheless, other studies did not find an association between bCUD

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and callosal microstructure [21]. This could be related to findings, showing that bCUD might not be a statistically reliable measure [22,18]. Furthermore, the assumption that bCUD reflects IHTT at all has been challenged. Saron et al. [23] identified some major issues with bCUD as a measure of IHTT. For example, bilateral frontal, central and occipital activations have been found in uncrossed conditions during as well as before hand reaction. This finding is at odds with the assumption of exclusively intrahemispheric processing during the uncrossed condition, thus questioning the validity of the bCUD calculation. Therefore, Saron and colleagues argued that the subtraction of uncrossed from crossed RT may contrast two forms of interhemispheric interaction with one another, instead of measuring a unified function of the corpus callosum.

A seemingly more promising method to analyze interindividual differences in IHTT can be found in recording EEG during the Poffenberger paradigm. The EEG Poffenberger paradigm utilizes the asymmetry of the onset times of event related potentials (ERP) following the presentation of the lateralized stimulus. Here, early ERP components (P1 and N1) recorded over the contralateral hemisphere are around 10–25 ms faster than over the ipsilateral hemisphere [23]. Therefore, an EEG based CUD (eCUD) can be calculated as the difference in latency of ERP components over homologous electrodes [18] which is interpreted as a more direct measure of IHTT. Similar to the behavioral Poffenberger paradigm, eCUD derived from the EEG Poffenberger paradigm has shown to be associated with callosal structure. For example, Westerhausen et al. [21] found a negative correlation between microstructural integrity of the corpus callosum's posterior third and eCUD ($r = -0.50$; $p = 0.001$). Thus, higher structural integrity in the corpus callosum is associated with faster interhemispheric transfer times. Interestingly, this association was only found for eCUD while no significant correlation between the callosal microstructure and bCUD was evident. Furthermore, eCUD also showed an association with another measure of white matter integrity, namely the axon diameter distribution. These results indicate strong evidence for the validity of eCUD as a measure of IHTT [24].

One major requirement for finding valid structure-function relations is a reliable paradigm to measure the function in question. Up to now, there are no studies investigating the long-term test-retest reliability of eCUD and bCUD. Since increasing number of studies are interested in determining functional correlates of callosal structure, such an evaluation is of utmost importance. To close this gap, the present study comprehensively investigated different reliability measures of eCUD, and compared these measures to bCUD. We tested for eCUD and bCUD both internal consistency within a session [25] and long-term test-retest reliability between two experimental sessions that took place one and a halve year apart. We also calculated an inter-rater reliability for the eCUD, as this measure could be biased by subjective evaluation during EEG data processing. Given the current replication discussion, we also report the correlation between the two measures, which has shown to be weak in a previous study [18].

2. Materials and methods

2.1. Sample size estimation

A statistical power analysis was performed for sample size estimation, based on a previous study [26] investigating the reliability of eCUD over one week. The effect size for ρ in this study was 0.79, considered to be extremely large using Cohen's [27] criteria. With an $\alpha = 0.05$ and $\beta = 0.95$, the projected sample size needed with this effect size is approximately $N = 11$ as calculated with G*Power 3.1 [28]. Hence, a minimum of 11 subjects is necessary for proving the objective of this study.

2.2. Participants

We acquired data from 31 German-speaking volunteers (14 males; mean age = 23.35 years; range 20–33 years) for the first session and re-invited them for the second session, approximately one and a halve year after the first one (mean number of months in between = 17.16). All participants had normal or corrected-to-normal vision and hearing and had no history of psychiatric or neurological disorders.

Handedness was assessed using Edinburgh Handedness Inventory. Due to technical issues with the EEG result evaluation, five participants were excluded from further analysis. The final sample consisted of 26 participants (13 males, mean age 22.96 years; range: 22–33 years). 10 out of 26 participants were left handers (mean LQ = −75.05) and the remaining 16 participants were right handers (mean LQ = 88.04). All participants were given written informed consent and were either paid or compensated with course credit. The ethics committee of the psychological faculty at Ruhr-University Bochum approved the study.

2.3. Experimental paradigm

The experiment was administered with Presentation software (Neurobehavioral Systems, Albany, CA, USA). Behavioral and electrophysiological testing was done simultaneously in a sound-attenuated room. The Poffenberger paradigm was conducted on an 18.9 inche wide screen and was based on previous studies [21]. Distance to the monitor was standardized at 57 cm with the help of a chin rest, thus 1 cm on the screen represented 1° of visual angle. The experimenter explained the task verbally before the beginning, with instructions to look at the fixation cross (0.5° diameter visual angle) and minimize movement during the task. Each trial of the task started with a short presentation (0.135 s) of a circular white stimulus (75.02 cd/m^2) on a grey background (20.20 cd/m^2) with a diameter of 1.41°. The outer edge of the stimuli appeared at 5° horizontal and 5° vertical distance from the fixation cross to the lower left or right visual half-field (left visual half-field: LVF; right visual half-field: RVF).

Participants were instructed to react as fast as possible after perceiving a stimulus regardless in which visual half field it was presented. Reaction time was recorded via button press on a keyboard with serial port. We excluded trials with an RT longer than 2000 ms from further analyses. Thus, the trial ended either when a valid reaction occurred or after 2000 ms. The following stimulus onset was jittered randomly between 1000 ms and 2000 ms in order to avoid expectancy effects. The task consisted of twelve experimental blocks, six for each hand. Each block consisted of 50 consecutive trials (25 for LVF and 25 for RVF). The order of sides of presentation was randomized but counterbalanced for each block. Before the beginning of the first experimental block, ten right-hand trials were presented to the participants to get familiarized with the experimental procedure. Conditions (RH_LVF, RH_RVF, LH_LVF, LH_RVF) were defined according to the combination of visual half field (LVF/RVF) and reacting hand (LH/RH). The maximal number of trials for each of the four conditions was 150.

2.4. EEG acquisition and analysis

EEG data obtained during the Poffenberger task were recorded with a 64 AG/AGCL electrode system (actiCAP ControlBox and QuickAmp 72, Brain Products GmbH, Gilching, Germany), positioned with standard international 10–20 system. We recorded the data with a sampling rate of 1000 Hz with FCz as reference electrode. Before the start of the experiment, we ensured that impedances of all electrodes were kept below 5k. The signal was digitized with a band-filter of 0.5–15 Hz (48 dB/oct). We used Brain Vision Analyser software (Brain Products GmbH) for further processing of raw data. After visual inspection, all EEG-sections containing technical artifacts were rejected. We used an independent component analysis (ICA) with infomax algorithm to eliminate artifacts, caused by blinks, eye movement or pulse. For most participants two or three ICA components that reflected artifacts (e.g. eye blinks or pulse) were excluded. In some participants up to 9 of 64 ICA components were excluded if there were clear technical or movement based artifacts, resulting in a non-physiological ICA component. Subsequently, previously rejected channels as well as the reference electrode (FCz) were calculated via topographic interpolation with spherical splines. The number of trials rejected by this procedure was lower than 5% for all participants. For further analysis, data was subdivided into stimulus-locked epochs starting 100 ms before and 600 ms after stimulus onset. All trials of the same condition underwent automatic artifact rejection and baseline correction before averaging. For each label described above, semiautomatic peak detection of N1 was performed for the homologous electrode pair O1 and O2. For N1 local maximum was set between 130 and 230 ms after stimulus onset. The resulting peaks were inspected visually afterwards and corrected, thus we ensured the peak to be the most negative point of the P1/N1 wave complex.

2.5. Measures of inter-hemispheric transfer time

Inter-hemispheric transfer times of behavioral Poffenberger and EEG Poffenberger were calculated for each individual participant. For the behavioral data, we calculated the crossed-uncrossed difference (bCUD) by subtracting the averaged RT of the uncrossed response conditions (e.g. RH_LVF) from the corresponding averaged RT of the crossed response conditions (e.g. RH_RVF). Likewise, the EEG-IHTT was calculated by subtracting the average latency of N1 peak onset derived from stimulus-ipsilateral electrode (e.g. LVF O1), from the average latency of N1 peak onset of the stimulus-contralateral electrode (e.g. LVF O2). The topography of the N1 is shown in Fig. 1. Notice that lateralized stimulus presentation indeed elicited a negative amplitude change with a source in the contralateral hemisphere. The O1/O2 electrode pair has been used in a number of other studies that investigated inter-hemispheric processing of visually evoked potentials [18]. We decided on reporting the eCUD calculated on the basis of N1 component. As other studies found, the N1 latency is more likely to refer to callosal transfer than P1 [29] and eCUD computed from N1 appears to be unconfounded [30]. Moreover, it was used as dependent variable in previous studies investigating IHTT and callosal microstructure [21,6,24].

2.6. Statistical analysis

All statistical analyses were performed using SPSS (version 20, SPSS Inc., Chicago, IL, United States of America). Testing was two-tailed with an α-level of 0.05. We used two lines of analyses to answer our research question: First, we computed the internal consistency for both RT data and EEG data, to show that participant's behavior and ERPs are consistent within a session. Second, we estimated the test-retest reliability to test whether both measures of IHTT were stable over time.

2.6.1. Reliability, internal consistency

We calculated internal consistency for both the first (T1) and the second (T2) measurement sessions by using the Spearman-Brown-Coefficient. This value can be interpreted as short-term reliability and was done separately for bCUD and eCUD as well as for the RT and N1 latency. For each of these four measures the Spearman-Brown-Coefficient was estimated by splitting up the conditions into two halves using an odd-even procedure. Each of these two halves consisted of blocks from the beginning, middle and the end of the experiment.

2.6.2. Test-retest reliability

To assess test-retest reliability between test session one and session two, we calculated Pearson's Correlation Coefficient for IHTT derived from each session. Test-retest reliability of reaction time based IHTT was determined using the average bCUD derived from both test sessions. Similarly, we evaluated the test-retest reliability of ERP based IHTT by correlating the average eCUD from both sessions with each other.

2.6.3. Inter-rater reliability

Since we used a semi-automatic procedure for peak detection of N1, we needed to ensure that result evaluation was independent from subjective rater effects. Therefore, a second rater repeated the EEG data processing for both the data sets from the first and the second session. The degree of agreement was assessed using a two-way, intra-class correlation coefficient (ICC) [31] for IHTTs between the first and second rater for both test sessions. This reliability measure indicates whether both raters show similar ratings of ERP selection.

2.6.4. Association between both metrics of IHTT

Finally, we determined the correlation between behavioral and ERP-based IHTTs. This analysis was a replication of earlier findings [18].

3. Results

In a first step, behavioral and EEG data were analyzed separately. For each of these measures of IHTT, we analyzed the internal consistency for both sessions separately (T1 and T2) and calculated the test-retest reliability of global metrics across sessions. The last section covers the results of the inter-rater reliability analysis and the relationship between both metrics of IHTT.

3.1. Behavioral RT data

Behavioral measures of IHTT from the first session (mean 2.47 ms; SD 4.62 ms; range between −8.05 and 10.94 ms) and from the second session (mean 4.31 ms; SD 5.25 ms; range between −7.21 and 21.06 ms) were comparable to earlier reports of bCUDs. In the first session 18 participants showed a positive bCUD. However, the bCUD of the remaining 8 participants was negative. In the second session 23 participants showed a positive bCUD, with only 3 participants showing a negative bCUD.

3.2. Internal consistency

We calculated short-term reliability as a measure of internal consistency. The analyses revealed low reliability of bCUDs for both sessions (first session Spearman-Brown-coefficient = 0.41; second session Spearman-Brown-coefficient = −0.44). Besides the analysis of the internal consistency for bCUDs, we assessed the same measure of consistency for RTs, which were the basis of computing the bCUDs. Analyses revealed a high internal consistency for both sessions, with very high Spearman-Brown-coefficient in the first (0.99) and second session (0.97).

3.3. Test-retest reliability

To assess the test-retest reliability, we correlated the averaged bCUD of the two sessions with each other and found a negative correlation between transfer times of both sessions ($r_{(25)} = -0.40$, $p < 0.05$, see Fig. 2).

3.4. EEG data

Average eCUD were computed over all conditions. Both average eCUDs of the first session (mean 20.58 ms; SD 12.98 ms; range between 2.50 and 49.00 ms) and second session (mean 24.06 ms; SD 17.62 ms; range between 2.50 and 65.50 ms) were within range of earlier reports (Saron et al., 2003). Average evoked potentials for the two electrode

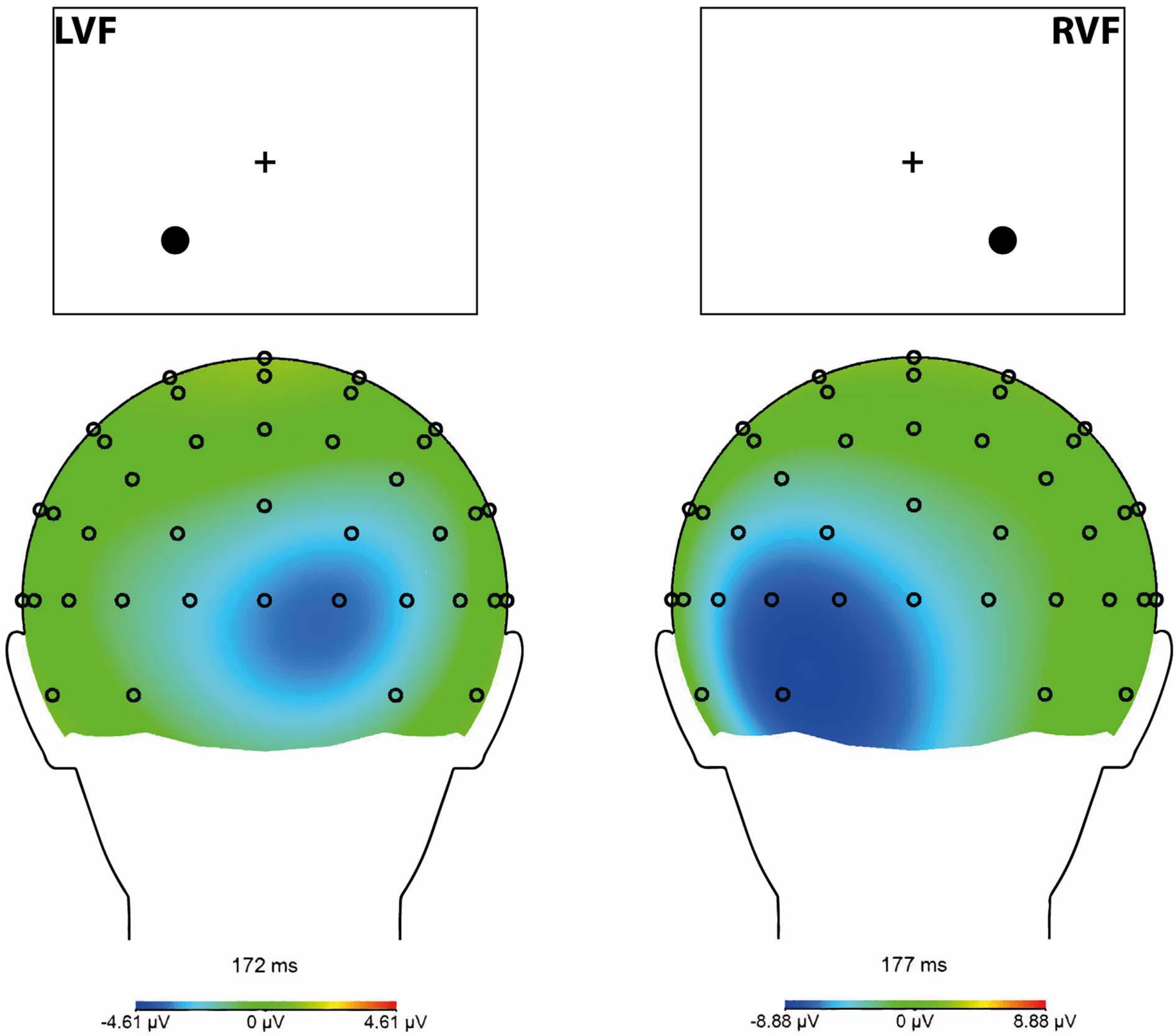

Fig. 1. Topography of N1 peak for one exemplary participant in the contralateral condition. The image shows the topographic source on the back of the head during the N1 peak timing. Panels above represent the task condition with stimulus presentation in left visual field (LVF) inducing negative amplitude changes in the right hemisphere or right visual field (RVF) inducing negative amplitude changes in the left hemisphere.

sites (O1 and O2) for each condition are shown in Fig. 3. Average N1 onsets of the two electrodes (O1 and O2) showed a similar pattern between the two test sessions (T1 and T2) for both conditions (LVF and RVF).

3.4.1. Internal consistency

Similar to the consistency analysis for the behavioral data, we calculated split-half reliability for eCUDs and N1 latency for electrodes contralateral to presented stimulus. This was done for both test sessions. The analysis revealed high internal consistency for eCUD in the first session (Spearman-Brown-coefficient = 0.99) as well as in the second session (Spearman-Brown-coefficient = 0.94). Subsequently, latency of N1-peaks derived from electrode positions contralateral to stimulus presentation (e.g. O1_RVF) were assessed as a comparable measure to the behavioral RTs. Thus the N1 peak should reflect the first consciously perceived processing of the stimulus in the relevant hemisphere. For both tests sessions the latency showed high internal consistency (first session: Spearman-Brown-coefficient = 0.94; second session: Spearman-Brown-coefficient = 0.98).

3.4.2. Test-retest reliability

To assess the test-retest reliability eCUD, we correlated the averaged eCUD of the two sessions with each other and found a high positive correlation between the transfer times of both sessions ($r_{(25)} = 0.81$, $p < 0.001$, see Fig. 4).

3.5. Inter-rater reliability for eCUD

The resulting ICCs for both sessions were in excellent range. For the first session we found an ICC of 0.85 between the two raters and for the second session an ICC of 0.84. These results indicate a high degree of agreement across raters [32].

3.6. Correlation between bCUD and eCUD

To assess the correlation between the two IHTT measures, we used two-tailed, pairwise correlation analysis over the average IHTTs of both sessions. Pearson's correlation coefficient revealed no significant correlation for the two measures of IHTT in neither the first session ($r_{(25)} = 0.24$, $p = 0.24$) nor in the second test session ($r_{(25)} = -0.16$, $p = 0.94$).

4. Discussion

Identifying reliable markers of callosal function is highly important within the framework of a more and more connectivity driven under-

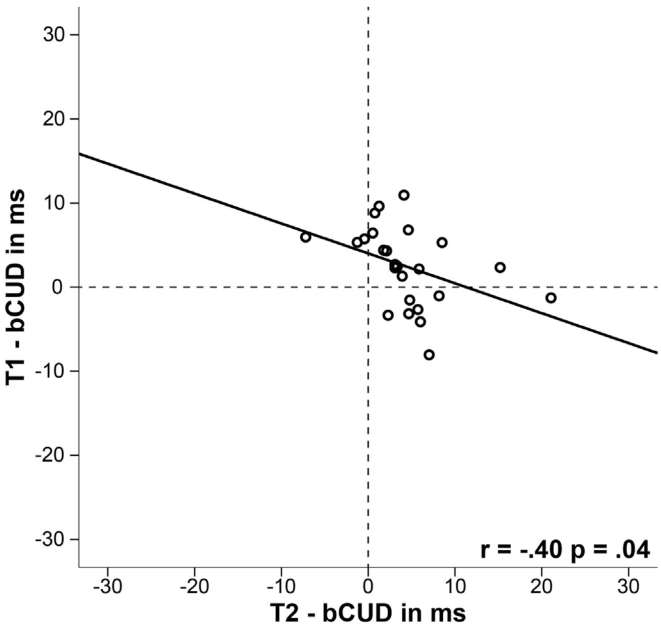

Fig. 2. Scatterplot of averaged bCUD in ms derived from the first session (T1) as related to the bCUD of the second session (T2). bCUD of both sessions show significant negative correlation (r = −0.40, p = 0.04).

standing of human cognition. In particular, asymmetrically organized cognitive systems like language [33,34] critically depend on callosal function. Therefore, the aim of the present study was to evaluate test-theoretical markers of the two different dependent measures of the Poffenberger paradigm, a widely used tool to determine inter-hemispheric transfer time. On the one hand, we computed IHTT from behavioral motor responses (bCUD) and on the other hand from electrophysiological measures (eCUD). Our analyses revealed striking reliability differences between the two versions.

The first measure we calculated was internal consistency, a measure related to short-term reliability. For the evaluation of the EEG based

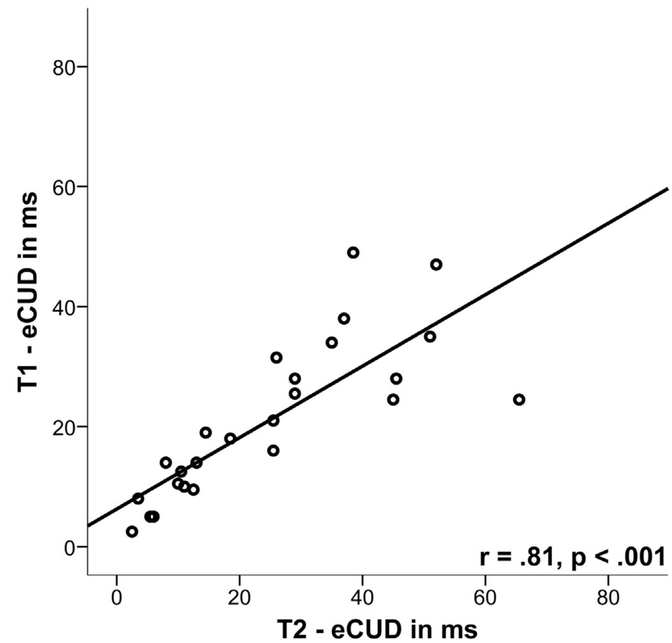

Fig. 4. Scatterplot of averaged eCUD in ms from the first session (T1) as related to the eCUD of the second session (T2). eCUD determined from N1 component at O1/O2 electrode positions. Correlation between eCUD of the two sessions shows significant relation of the two measures of IHTT (r = 0.81, p < 0.001).

Poffenberger, both the N1 latencies as well as eCUDs are highly consistent, reflected in Spearman-Brown-coefficients over 0.90 in both sessions. In contrast, in the behavioral paradigm only RTs were consistent in both sessions (Spearman-Brown-coefficient > 0.90 in both sessions), indicating that Individual RTs per se were reliable. However, the bCUD's internal consistency for the first session was below the criterion of < 0.41. Moreover, bCUD had a negative Spearman-Brown-coefficient (= −0.44) for the second session. Therefore, the internal consistency of the bCUD cannot be interpreted as reliable.

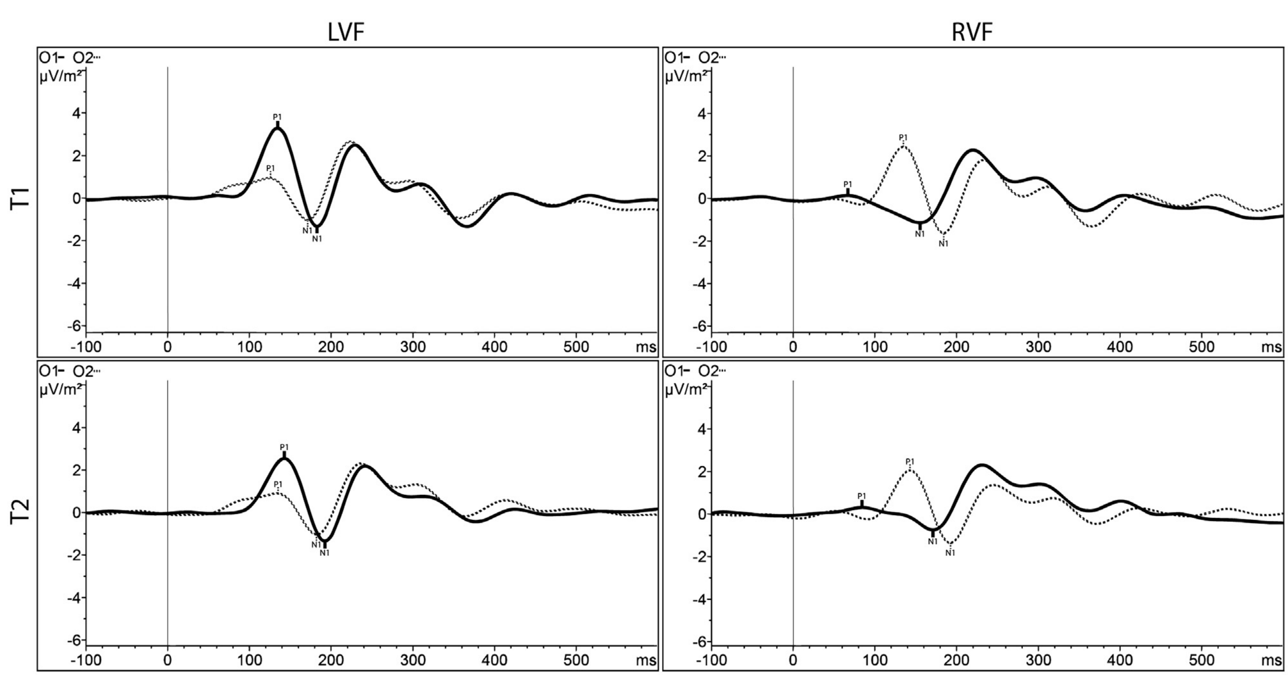

Fig. 3. Averaged evoked potentials at O1 and O2 electrode positions after presentation of visual stimulus on the left visual field (LVF) or right visual field (RVF). The figure shows the amplitude over time for the first session (T1) and second session (T2). Notice that O1-electrode is over the left hemisphere and O2-eletrode over the right hemisphere. As expected, both components (P1 and N1) have shorter peak latencies over the contralateral hemisphere.

The second measure we calculated was the test-retest reliability in form of Pearson's correlation coefficient between CUDs for the first session and CUDs for the second session. This analysis showed similar results between the two different Poffenberger paradigms. eCUDs of the two sessions were significantly correlated with each other and showed a high correlation coefficient ($r_{(26)} = 0.81$, $p < 0.001$), indicating a high test-retest reliability of the EEG based estimate of IHTT. In contrast, correlation analysis of test-retest reliability bCUD shows a comparable weak and negative correlation. This result indicates that this measure is not stable over time and possible an inappropriate estimate of IHTT.

To ensure that our semi-automatic procedure for peak detection does not bias the ERP results, a second evaluator repeated the analysis. eCUD calculated by the first evaluator was correlated with eCUD calculated on basis of peaks that were picked by the second evaluator. For both sessions, eCUDs of the first and second evaluator were correlated with each other with a correlation coefficient above 0.84, providing a high inter-rater reliability for eCUD.

Finally, as expected from earlier studies [18], correlation analysis of bCUD and eCUD showed no significant relation between the two measures of inter-hemispheric transfer. As discussed by others [21,6], this might be due to differences in the underlying process, which is measured by the two versions of the Poffenberger paradigm. While bCUD reflects a visuomotor transfer, eCUD reflects an exclusive transfer of visual perceptive information.

Our results revealed that the eCUD showed consistently higher reliability estimates than bCUD. Although EEG measurements have some caveats (e.g. measurement of non-spherical skulls, increase in alpha signal over the course of an experimental session), IHTTs of ERP measures seem likely to have a better signal-to-noise ratio than the behavioral measure, resulting in higher reliability of the former. On the one hand, the EEG Poffenberger paradigm is a much more direct measurement of inter-hemispheric transfer, since the callosal conduction velocity of the splenium is about 7 ms, with a total inter-hemispheric delay of 15.4 ms (range: 2.6–18 ms) [35]. IHTTs measured by eCUD typically lie between 8 and 30 ms [18,36,37], which fits within the range shown in studies of axonal conduction velocities of the corpus callosum [38]. On the other hand, IHTTs measured by bCUD lie approximately between 3 and 5 ms [18,39]. This speed of transfer could only be achieved by myelinated callosal axons with large diameter between 2.5–6 µm [40] but such commissural axons only account for about 10% of callosal fibers [41] in general.

Additionally, eCUD reflects processes of fewer neural components than bCUD. While eCUD is calculated on the basis of electrophysiological events, which are thought to reflect perceptual processes, bCUD involves at least both the perceptual component and a motoric component. Hence, precise and more direct estimates of the inter-hemispheric transfer time – that is the additional processing time caused by the crossing of the hemispheric gap – are better assessed via the EEG version of the Poffenberger paradigm.

In our study, EEG measures seem to be advantageous in reflecting the IHTT compared to the behavioral counterpart, which shows weak reliability. The reason for the relatively weak test-retest reliability of bCUD is still a matter of debate. Different factors might be contributing to the low signal-to-noise ratio: First, RT based IHTTs are computed from behavioral measures only. This implies that the neural route of processing cannot be inferred from this kind of transfer time. Thus, it is unclear whether the behavioral transfer times are caused by visual information transfer in the splenium or by motor process transfer in the posterior midbody of the corpus callosum. Additionally, both kinds of interhemispheric transfer might contribute to the behavioral IHTT, but the extent cannot be assessed either. Second, the number of neural components along the way from visual perception to a behavioral reaction of a hand is numerous and the neural pathway involved in this computation is not well understood. Thus, the reaction time is not a direct reflection of either interhemispheric transfer, but is also partially based upon motor output processing. A third possible influence for the unstable bCUD comes from the mentioned motor process, which can be biased by the participant. For example, uncertainty of stimulus detection might play a role, as well as motivational factors. All of these factors are possible contributors to low reliability.

The assumption of low signal-to-noise ratio is in line with studies, showing negative transfer times [42] as well as biased estimations of transfer directionality. In the current study, negative bCUDs were evident in eight participants during the first experimental session and three participants during the second experimental session. Interestingly, the direction of bCUD was not stable in these participants as there was no overlap between the negative bCUD participants of the first and second session (see Fig. 2). Hence, the negative bCUD values might cause the negative correlation between first and second session. As discussed by Saron et al. (2003), the interpretation of these negative bCUD is rather unclear. A possible explanation for the occurrence of this phenomenon is discussed in Chaumillon et al. [43]. Chaumillon et al. assessed callosal transfer from left to right and vice versa in a behavioral Poffenberger paradigm, comparing left and right-handed participants with regard to their eye dominance. Interestingly, their results showed a negative transfer time for participants with left eye dominance when bCUD was calculated from left to right, with the strength of effect being moderated by handedness. Therefore, eye dominance might cause negative transfer times in bCUD, but it is yet unclear if eCUD is also influenced by eye dominance – an issue that should be addressed in future studies. Furthermore, Iacoboni and Zaidel [22] stated that bCUDs computed over 2400 and up to 12,000 trials are extremely similar across a sample of three subjects. Additionally, they reported that bCUD variability across several sessions in a single subject tend to mimic the variability in a sample of subjects tested within one session. Taken together, this implies that bCUD can hardly be used to determine a trait such as interhemispheric transfer on an individual scale.

Nevertheless, bCUD has been shown to be a valid method for comparisons between healthy participants and neuropathological groups. For example, differences in inter-hemispheric transmission were shown in split-brain patients [44], as well as in patients with callosal agenesis, compared to healthy controls [45]. Additionally, although there appears to be no difference in inter-hemispheric transfer in schizophrenic or bipolar patients compared to healthy subjects, an abnormal redundant signal effect was found in these patient groups with the help of the behavioral Poffenberger paradigm [46].

5. Conclusion

Using psychophysiological tasks to infer underlying neural processes is certainly challenging and only achievable if neuroscientists are provided with reliable techniques for measuring the process of interest. Using the Poffenberger paradigm, which is the method of choice for investigating inter-hemispheric transfer times in humans, we evaluated two ways of conducting this experiment – as a behavioral task or an EEG experiment. Our results are in favor of computing transfer times via ERP measures, because such IHTTs were consistent within one test session as well as reliable on a subject-level between two sessions with a one and a halve year of delay. Thus, we suggest that the application of EEG during the visual Poffenberger experiment is a meaningful addition, which enables the computation of reliable estimates of interhemispheric transfer time. This is important especially for studies, which relate differences of interhemispheric processes to variability in neural structures.

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