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ORIGINAL ARTICLE

Interhemispheric transfer time differences in different frequencies between fast and slow healthy adult readers

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ABSTRACT

Objectives: The main objective of our study was to investigate the role of the interhemispheric callosal network, specifically focusing on the interhemispheric transfer times of different frequency bands during word reading.

Patients and methods: This experimental study involved healthy volunteers. Interhemispheric transfer time was calculated as the latency difference of event-related potentials between the contralateral and ipsilateral hemispheres. Interhemispheric transfer times for alpha, theta, and beta frequency bands were separately calculated in electroencephalogram recordings during word reading. We then analyzed differences in interhemispheric transfer times between fast and slow adult readers, with a particular focus on the directionality of interhemispheric transmission.

Results: Our findings revealed a specific slowness in right to left transmission within the alpha band for slow readers.

Conclusion: Slower interhemispheric transfer time during word decoding and lexicon access in slow readers may be attributed to a neuronal synchronization problem caused by alpha oscillations in smaller-diameter axonal callosal channels. Considering the existing research on alpha oscillation and attention networks, we propose that this result may indicate a difference in attention processes between the two groups. The study sheds light on the importance of callosal network dynamics, specifically alpha oscillations in reading, offering insights into the underlying neural mechanisms and potential attention-related differences between fast and slow readers.

Keywords: Alpha band, hemispheric lateralization, interhemispheric transfer times, oscillation, word reading.

Reading involves the integration of various cognitive processes, such as visual perception, phonological processing, and semantics. Neural oscillations in different frequency bands coordinate and synchronize these processes, enabling efficient and effective reading. Alpha oscillations play a role in suppressing irrelevant or distracting information during reading.[1] Theta oscillations are associated with lexical and semantic processing, which is important for accessing word meanings in the lexicon,[2] and gamma oscillations play a role in attention orienting.[3] Accordingly, reading difficulty is associated with neuronal synchronization impairment.[4] Reduced neural network integration and reduced communication were demonstrated in individuals with dyslexia compared to typical readers in the alpha oscillations,[5] theta oscillations,[6] and all frequency bands.[7]

Information transfer between hemispheres occurs mainly through the corpus callosum. This axonal network plays a vital role in the integration of brain functions mentioned above. According to the interhemispheric deficit theory, reading difficulty occurs because of the disruption of callosal transfer.[8] Supporting this theory, some studies demonstrated that posterior corpus callosum abnormalities might affect reading abilities.[9-11]

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The speed of callosal transmission can be calculated using latencies of visual evoked potentials obtained from homologous sites on the scalp to lateralized stimuli presented from either the left visual field (LVF) or the right visual field (RVF). The difference in latency between the left and right hemispheres is defined as interhemispheric transfer time (IHTT).[12] Previous studies have typically calculated IHTT using the latency differences of early visual event-related potential (ERP) components such as P1 and N1, recorded at homologous occipital or parietal sites in response to lateralized visual field stimulation.[13-15] In the present study, IHTT was calculated based on the latency difference of the N1 component, which is known to reflect early visual processing and hemispheric transfer of information across the corpus callosum. The corpus callosum consists of fibers with different diameters and conduction speeds.[16] Because the evoked potentials are the combination of synaptic activities and fiber oscillations at different frequencies,[17] the use of oscillations for the calculation of IHTT can provide more detailed information about the callosal transfer. Accordingly, Nalcaci et al.[12] reported that callosal channels that oscillate between 4–8 Hz, 8–15 Hz, 15–20 Hz, and 20–32 Hz exist. Moreover, the IHTT measured by P1 differed between these bands for visual stimuli.

Martin et al.[15] reported that adults with dyslexia and controls had differences in IHTT, which was calculated by N1 elicited during word reading. In a previous study,[18] we grouped healthy individuals as fast and slow readers according to their word/pseudoword reading speed and applied an experimental design similar to that of Martin et al.[15] It was observed that slow readers had a slower right to left IHTT only in the parietal region, which is involved in early visual word decoding. Moreover, the difference was specific to real words, whereas the groups differed in neither pseudoword nor grating stimuli. We suggested that the difference may originate at the orthographic visual lexical level rather than at earlier basic visual processing.

In the current study, we reanalyzed the EEG data belonging to the word stimuli condition in our previous study. We examined IHTT separately for fundamental frequency bands (alpha, beta, delta, and theta) in fast and slow readers. Considering the role of oscillatory activity in integration and studies showing integration problems in reading difficulties, we hypothesized that our previous findings may be related to a callosal channel oscillating at a specific frequency. To the best of our knowledge, this is the first study to examine frequency-filtered, ERP-based IHTT estimates during word reading.

PATIENTS AND METHODS

The EEG data of 51 right-handed participants who took part in a previous study[18] were used. We utilized a word and pseudoword reading test developed by Güldenoğlu[19] to determine slow and fast reader groups. This validated and reliable test consisted of two subtests: word pairs (42 pairs of real words) and pseudoword pairs (42 pairs of legal pseudowords). Each included 21 identical and 21 different word or pseudoword pairs. The pseudowords were constructed based on Turkish orthographic and morphosyntactic rules. The pairs were presented in a randomized order, but the sequence of word and pseudoword pairs was fixed. The order of the subtests was counterbalanced among participants to minimize order effects. The test was administered using the DMASTR software, developed by Forster and Forster[20] at Monash University and the University of Arizona. This software records response times and accuracy. Word and pseudoword pairs were displayed horizontally, with the left word in Times New Roman font and the right word in a handwriting script. Each pair had the same number of letters and syllables. Participants were instructed to determine as quickly as possible whether the words or pseudowords in each pair were identical or different by using the keyboard's right and left shift keys. For example, if no response was provided within 3500 msec, the next pair automatically appeared. Written informed consent was obtained from all participants. The study protocol was approved by the Ankara University Faculty of Medicine Clinical Research Ethics Committee (Date: 25.09.2027, No: 15-985-17). The study was conducted in accordance with the principles of the Declaration of Helsinki.

The test was conducted with 309 healthy university students (182 females, 127 males; mean age: 19.72 ± 1.69 years; range, 18 to 25 years), all of whom were native Turkish speakers with no history of reading disorders, learning disabilities, neurological or psychiatric conditions, or medication affecting the central nervous system. This participants achieved high accuracy scores (39 ± 1.9 for the word subtest and 39 ± 2.03 for the pseudoword subtest). However, response times varied: the word subtest was responded in 828.15 ± 144.36 msec, and the pseudoword subtest was responded in 1067.57 ± 218.25 msec. Response times for correct answers were used to classify participants. Those with response times exceeding 0.5 standard deviations above the mean in both subtests were categorized as "slow readers." Participants who did not meet these criteria were grouped as "fast readers." This approach mirrored methods used in similar studies, such as Jordan et al.[21] and Rayner et al.[22]

The cutoff values were set at mean + 0.5 × standard deviation to account for the left-skewed distribution of response times in this sample. By targeting the higher end of the distribution, we ensured that slow readers represented a distinct subset within this healthy, high-performing cohort. The participants were university students, and the accuracy scores observed in the behavioral test were close to the maximum value, given that the prerequisite for admission to higher education institutions in Türkiye is to pass a central entrance examination. Reading speed was left-skewed, resulting in a higher proportion of participants with high reading speed among those who underwent EEG assessment. Thus, the sample consisted of 36 fast readers (22 females, 14 males; mean age: 20 ± 1.35 years; range, 19 to 24 years) and 15 slow readers (8 females, 7 males; mean age: 21.06 ± 1.62 years; range, 18 to 24 years).

All participants had normal or corrected-to-normal vision. They were right-handed as assessed by the Hand Preference Questionnaire[23] adapted to Turkish.[24] According to this questionnaire, individuals who score between 13 and 17 are accepted right-handed. In slow and fast readers, the mean score was 14.26 ± 1.75 and 14.23 ± 1.26, respectively. The handedness scores did not differ from each other (Student's t-test; $p > 0.05$).

Stimuli

The averaged EEG data from the silent word reading task, in which a significant group difference was observed in the previous study, was analyzed. There were 60 high-frequency Turkish nouns with five letters and two syllables (e.g., "KA-LEM" [PEN-CIL]) were selected from the word frequency dictionary of Turkish. The average lexical frequency of the words was $193/10^6$ All words were presented in uppercase Times New Roman font. They appeared in black text on a grey background. The stimuli were measured 0.95° in height and 5.72° in width when displayed on a 17-inch monitor viewed from a distance of 60 cm. The monitor operated at a refresh rate of 60 Hz. The experiments were programmed in MATLAB using the Psychophysics Toolbox extensions.[23-25] The sequence began with a fixation marker appearing at the center of the screen for 2500 msec, followed by a 50 msec blank interval. The fixation marker then reappeared for 200 msec and disappeared again for 50 msec. Next, the first stimulus was presented for 50 msec. During the interstimulus interval of 1250–1350 msec, only the fixation marker was visible. The stimuli display duration was constant throughout. A trigger signal was sent to the EEG system immediately upon stimulus presentation.

A word was presented horizontally in five different positions.[15] The first, second, third, fourth, or fifth letter of the word randomly appeared at the center of the screen in each trial. In the LVF condition, the fifth letter of the word coincided with the center. In the RVF condition, the first letter of the word coincided with the center. Participants were asked to look at the fixation mark (a black '+') in the middle of the screen and silently read the words. At the end of each set, participants were asked to recall the last word to confirm active engagement and attention to the stimuli. Breaks lasting 2 to 3 min were provided between sets. Figure 1 shows the experimental design and setup.

Electrophysiological data collection and analysis

In the previous study, EEG data were obtained from 30 channels according to an extended 10-20 system with a sampling rate of 1000 Hz (Brain Vision Recorder 2.1 and Easycap, Brain Products GmbH, Gilching, Germany). Electroencephalogram recordings were conducted in a dimly lit room, isolated from electromagnetic interference and sound. Horizontal and vertical eye movements were monitored using electrooculogram recordings. Electrode impedances were maintained below 20 kΩ.

BrainVision Analyzer version 2.1 (Brain Products GmbH, Gilching, Germany) was used for analysis. Event-related potentials were elicited by averaging the filtered (0.5-40 Hz), segmented (200 msec prestimulus and 800 msec poststimulus), and artifact-free data. Trials containing saccades or blinks were identified and excluded using ± 100 μV artifact rejection thresholds and subsequent visual inspection. Only artifact-free epochs were included in the averaging procedure to ensure that the LVF/RVF conditions were not affected by ocular

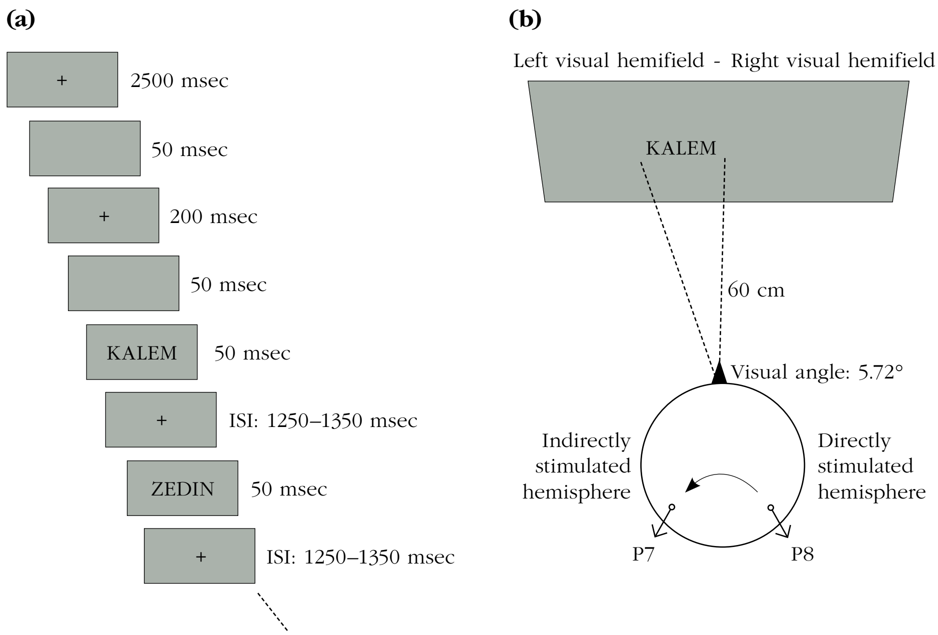

Figure 1. (a) Experimental design and setup. **(b)** Sequence of stimulus presentation.
Schematic representation of the experimental setup (adapted from Artuvan et al.[18]).

movements. Because a significant group difference was found at the parietal region for N1 peaks in the previous study, we used the averaged data at parietal leads (P7-P8).

In this study, the grand averages were separately obtained for the fast and slow reader groups for each group. Afterward, a fast Fourier transform was applied to the grand averages solely as an exploratory step to observe the dominant frequency ranges contributing to the evoked response, not as a quantitative analysis of oscillatory activity (Figure 2). Importantly, fast Fourier transform coefficients were not used as dependent variables, were not statistically analyzed, and were not interpreted as direct measures of rhythmic brain activity. Based on the frequency ranges identified in this exploratory step, standard band-pass filters were applied at 0–4 Hz, 4–8 Hz, 8–14 Hz, and 14–24 Hz, respectively. Following filtering, N1 peak latency was identified separately for each frequency band (100 to 200 msec for delta, 125 to 200 msec for theta and alpha, and 125 to 185 msec for beta). This analytical strategy followed the conceptual framework proposed by Nalcaci et al.[12] and Ulusoy et al.,[26] in which frequency-constrained evoked responses were used to probe parallel interhemispheric transfer channels while transfer time itself was quantified in the time domain. We marked the N1 peak latencies in each individual data for each oscillatory band. Because of one missing data point in the fast reader group, our analysis was conducted using data from 50 individuals.

Sample size determination

Power analysis was performed before the study using G*Power version 3.1.9.7 software (Heinrich-Heine Universität Düsseldorf, Düsseldorf, Germany) to calculate the optimal number of participants needed in the study to achieve 95% power to detect a significant interaction between repeated measurements and groups in a repeated measures analysis of variance (ANOVA). For six repeated measurements (2 × 3) and two groups, with a type I error rate of 0.05, and a correlation of 0.5 among repeated measurements, 44 individuals were required to detect an interaction effect (Cohen's f = 0.20).[21,22]

Calculating IHTT and statistical analysis

The difference in N1 latencies obtained from homolog electrodes P7 and P8 was calculated as the IHTT in milliseconds. The transfer time from the right hemisphere to the left hemisphere was estimated by subtracting the contralateral response (i.e., the directly stimulated right

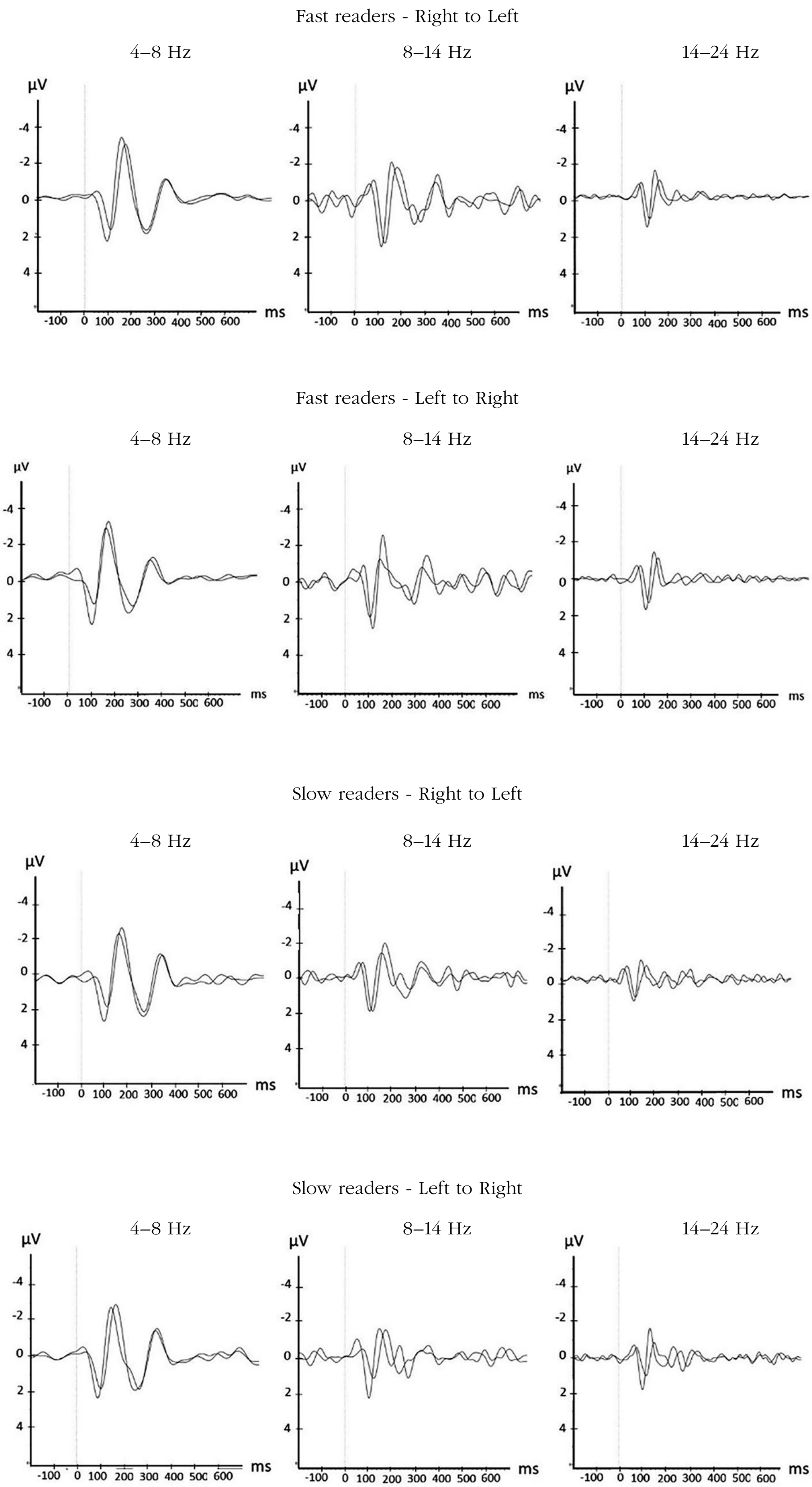

Figure 2. Grand averaged data for 4-8 Hz, 8-14 Hz, and 14-24 Hz in fast and slow readers over P7-P8 electrodes.

hemisphere response to LVF condition) from the ipsilateral response (i.e., the indirectly stimulated left hemisphere response to LVF condition) or vice versa (Figure 3).[27,28] The IHTT values were calculated for each frequency band and both directions separately for each participant.

The IBM SPSS version 20.0 software (IBM Corp., Armonk, NY, USA) was used for statistical analysis. The Mann-Whitney U test was used for between-group comparisons, the Wilcoxon test for within-group comparisons, and repeated measures ANOVA for IHTT analysis. Analysis of variance was applied to the IHTT values across the three frequency bands, excluding the 0–4 Hz delta band due to significant artefacts. The analysis included two within-subject factors: two directions (left-to-right and right-to-left) and three frequency bands (theta, alpha, and beta). The between-group factor consisted of slow and fast readers. To determine statistical significance, we used a threshold of $p < 0.05$. The effect sizes were assessed based on suggested norms for partial eta-square (small = 0.001, medium = 0.06, large = 0.14) as recommended by Pallant.[29] In the case of significant effects, we conducted pairwise comparisons. Pearson correlation analysis was performed to determine the significant interaction effects.

RESULTS

Based on the response time statistics from the word and pseudoword reading tests, slow readers demonstrated significantly longer response times than fast readers in both tests (Mann-Whitney U test; $p < 0.001$). Additionally, pseudowords elicited longer response times compared to words for both fast readers ($p < 0.001$) and slow readers (Wilcoxon test; $p = 0.001$).

There was no significant difference in sex distribution between the groups, as determined by the Pearson chi-square test ($p > 0.05$). An age difference was observed between the fast readers and slow readers ($p = 0.046$). However, given the homogeneity of the sample (narrow age range, right-handedness, and education level) this difference was deemed negligible; thus, it was not considered a confounding factor in the repeated-measures ANOVA.

The mean estimated IHTTs of the groups are presented in Figure 4, and Table 1 summarizes the corresponding numerical IHTT values. The ANOVA revealed a significant main effect of frequency (F = 7.194; df = 2,96; $p = 0.001$; $\eta^2p = 0.13$). Interhemispheric transfer time in the alpha frequency band (18.395 ± 1.607 msec) was slower than both theta (13.057 ± 1.23 msec) and beta (15.357 ± 1.269 msec) bands ($p < 0.001$ and $p = 0.05$, respectively). The main effect of direction was insignificant ($p > 0.05$). Frequency × Group interaction effect was significant (F = 3.63; df = 2.96; $p = 0.030$; $\eta^2p = 0.070$). Partial eta-square showed that the effect size was between medium and large.[29] The moderate-to-large effect size reinforced the practical importance of this interaction, suggesting that the variations across groups in response to frequency were not trivial and could have meaningful implications. An additional power calculation was performed with G*power version 3.1.9.7, considering the effect size, sample size, and alpha level. The power with these variables was found to be 0.87. According

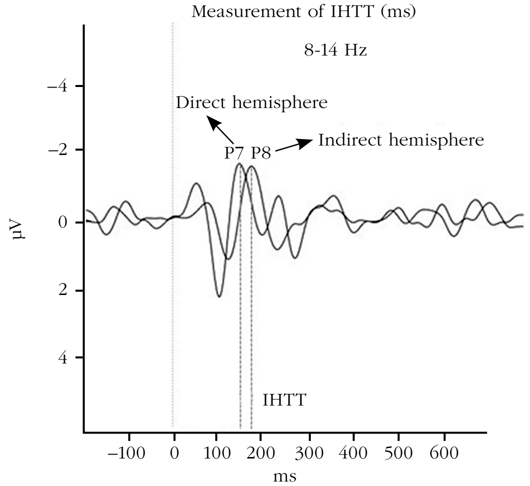

Figure 3. Interhemispheric transfer time measurement method by event-related oscillations.

IHTT: Interhemispheric transfer time.

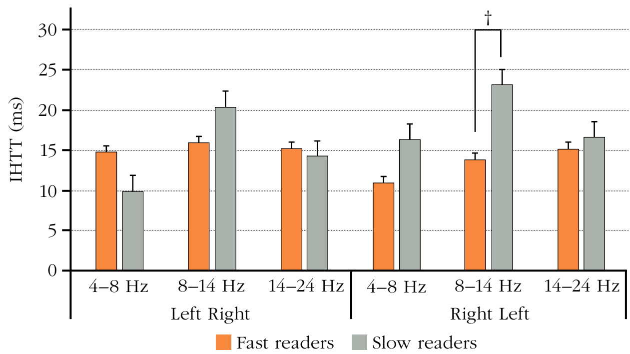

Figure 4. The mean IHTTs in milliseconds for the theta, alpha, and beta frequency bands.

IHTT: Interhemispheric transfer time.

TABLE 1
Interhemispheric transfer time (msec) across frequency bands and directions in fast and slow readers

		Fast readers (n=35)	Slow readers (n=15)
Direction	Frequency band (Hz)	Mean ± SD	Mean ± SD
	Theta (4–8)	14.8 ± 13.4	10.0 ± 21.0
Left → Right	Alpha (8–14)	16.0 ± 15.1	20.5 ± 25.2
	Beta (14–24)	15.3 ± 12.7	14.3 ± 13.9
	Theta (4–8)	11.0 ± 14.9	16.4 ± 18.0
Right → Left	Alpha (8–14)	13.9 ± 15.5	23.2 ± 14.6
	Beta (14–24)	15.2 ± 12.0	16.7 ± 12.2

SD, standard deviation.

to pairwise comparisons, there was no significant difference between the frequency bands in the fast readers ($p > 0.05$). However, in the slow readers, IHTT in the alpha band (21.833 ± 2.689 msec) was slower than both the theta (13.2 ± 2.058 msec) and beta bands (15.5 ± 2.123 msec; $p = 0.001$ and $p = 0.047$, respectively). The difference between the groups was significant only in the alpha band ($p = 0.037$). According to the post hoc test, there was a trend toward a significant increase in right to left transfer in slow readers ($p = 0.055$). The correlations between the response time to words/pseudowords[19] and the IHTTs at different oscillations were insignificant in the whole group ($p > 0.05$). Regardless of the direction, there was a correlation between the oscillations alpha and beta ($r = 0.401$; $p = 0.004$), alpha and theta ($r = 0.553$; $p < 0.001$), and beta and theta ($r = 0.452$; $p = 0.001$).

DISCUSSION

In our previous study, using a word reading task, we found that slow readers had longer right to left IHTT than fast readers, even without a diagnosis of dyslexia. Slower IHTT in slow readers was attributed to a problem in the transmission of information from the right hemisphere to the visual word form area in the left hemisphere. In the current study, we aimed to observe whether slowness occurred in a specific callosal channel. We calculated the IHTT at parietal leads for three frequency bands: alpha, beta, and theta. The results showed that IHTT in the alpha band differed from the beta and theta bands. Moreover, only in the alpha band, IHTT was longer in slow readers than in fast readers. Thus, we found that the slowness was specifically related to alpha band-filtered ERP components in the corpus callosum, reflecting frequency-weighted interhemispheric dynamics. The present findings should be interpreted within the framework of the parallel callosal channel model, which proposes that interhemispheric transfer is mediated through multiple pathways characterized by distinct frequency properties. This model was first introduced by Nalcaci et al.[12] and subsequently elaborated by Ulusoy et al.,[26] who demonstrated that frequency-specific components of evoked responses were associated with different interhemispheric transfer delays and callosal fiber populations.

Comprehensive reviews have highlighted substantial evidence supporting the link between reading difficulties and impaired interhemispheric interaction.[27-31] The structural and functional abnormalities of the corpus callosum have been observed in connection with reading disorders.[32-36] Furthermore, these morphometric differences have been found to correlate with the degree of impairment in tests measuring phonological abilities.[33] However, we did not find any study analyzing the reading speed in relation to oscillations in callosal fibers. Investigating oscillations in callosal fibers might reveal how interhemispheric communication contributes to reading proficiency and differences in reading speed. Such research could enhance our understanding of conditions such as dyslexia, where disrupted interhemispheric connectivity has been implicated. Although not always explicitly framed in terms of callosal channels, several subsequent studies investigating interhemispheric communication and reading-related processes have reported frequency-specific alterations, particularly in the alpha band, using ERP, EEG, and magnetoencephalography approaches, providing converging support for frequency-dependent interhemispheric transfer mechanisms. Identifying the role of callosal oscillations might open avenues for targeted therapies, such as neurofeedback or transcranial magnetic stimulation, to improve reading skills. Our seminal findings may lead the way to these advances.

Callosal axons include feedforward and feedback association pathways for advanced and basic processing. Callosal subregions are defined by axon properties, with each differing in axon density, size, and level of myelination.[13,32] The energy percentages of visual evoked potentials suggest that theta and alpha bands correspond to the activation of callosal fibers 0.4 to 1 μm in diameter, while beta-1 and beta-2 bands reflect the activation of fibers 1 to 3 μm in diameter.[26] The process of interhemispheric integration occurs simultaneously across multiple channels, with the impact of integration speed differing between channels.[37] The term "callosal channel" is used to describe specific pathways within the corpus callosum that connect particular areas in each hemisphere. Nalcaci et al.[12] supported the callosal channels hypothesis, showing that specific oscillation patterns occurred in callosal channels during visual processing. The study found significant differences in the alpha, theta, beta-1, and beta-2 frequency bands.[38-40] Oscillatory synchronization has been proposed as an important organizing principle for interhemispheric communication. In a notable animal study, the researchers disrupted the corpus callosum of cats and examined oscillatory responses. In the intact condition, the responses from left and right area 17 within each hemisphere oscillated synchronously, while no synchronization was observed between the two hemispheres in the disrupted condition, indicating that interhemispheric synchronization depended on the oscillating fibers throughout the corpus callosum.[41] The theory of oscillatory neural groups, which is supported by neuroanatomical findings, proposes that selectively distributed neural interactions can support functional unification across distant cortical regions.[42]

Our findings indicate an alpha band-specific difference in interhemispheric transmission related to reading skills. The alpha-oscillated IHTT was longer than the beta and theta bands; however, the beta and theta bands did not differ from each other. Additionally, the alpha oscillation was correlated with beta and theta. These results indicate that smaller-diameter axonal channels may be linked to variations in reading speed. Consistent with our finding, Fraga González et al.[43] found a significant group difference only in the alpha band during rest in dyslexics compared to typical reading adults in a connectivity strength study. The groups were similar in terms of delta, theta, and beta frequency bands. Magnetoencephalography studies have shown frequency-specific alterations in interhemispheric communication. Vourkas et al.[5] reported reduced network efficiency in the alpha band in poor readers. Hinkley et al.[44] reported that abnormal callosal development leads to selective disruptions in alpha-band functional connectivity, particularly between the dorsolateral prefrontal, posterior parietal, and parieto-occipital cortices, which were associated with cognitive impairment. Their results highlighted that alpha oscillations played a key role in functional integration across hemispheres. In line with this, the alpha-specific slowing observed in our study may reflect subtle variations in callosal fiber integrity or efficiency that influence higher-order cognitive and linguistic processing, even in healthy readers. Alpha oscillations are considered a facilitator in maintaining the brain's focus on relevant tasks and suppressing irrelevant or distracting information.[1] These oscillations play a role in maintaining the balance between specialized functions by regulating the transfer of relevant information across the corpus callosum.

The decoding processes involved in word reading engage brain circuits associated with visual, auditory, and linguistic processing. According to the bilateral projection theory, visual information from both hemifields is projected to each hemisphere, whereas the split fovea theory proposes that each hemifield projects exclusively to the contralateral hemisphere, requiring interhemispheric transfer for whole-word processing.[15,45-47] Kim and Nam[48] demonstrated that foveal word recognition involves hemispheric inhibitory mechanisms that support the split fovea theory rather than the bilateral projection theory. In line with this view, the alpha-specific delay in interhemispheric transfer observed in slow readers in our study may reflect reduced efficiency of callosal communication between hemispheres, leading to weaker integration of visual word information processed separately in each hemisphere. The posterior word recognition systems, along with the visual word form area located in the left occipitotemporal region, play a prominent role in these decoding mechanisms.[26,37,49] In a previous study, it was observed that slow readers had a slower right to left IHTT only in the parietal region, which is involved in early visual word decoding.[18] A structural abnormality (e.g., developmental myelination inefficiency) may be one of the causes of slowness in alpha band-filtered ERP components reflecting frequency-weighted interhemispheric dynamics. It is also possible that the strength and timing of alpha oscillations in one hemisphere could interact with the transfer of attention-related information across the corpus callosum. Although we did not have an experimental design with an irrelevant or distracting stimulus, one of the explanations of the finding might be the relationship between alpha oscillations and attention. Studies that would directly reveal this relationship would be beneficial in the future.

Even if the power analysis results showed an adequate sample size, we assume the small sample size and the imbalance in the number of participants across groups as a limitation. Given that our behavioral data was skewed to the left, having more samples from the left cluster ensured that the distributional properties of the data were preserved in our data. Otherwise, nondistributional selection would have led to bias. Having more participants would enhance the statistical significance and increase the estimated power. Another limitation was that we did not determine whether the female participants were in the luteal phase of their menstrual cycle. Evidence suggests that the latency of the indirect right-to-left IHTT is negatively affected during the luteal phase.[50] Under these circumstances, we were not able to interpret the relationship between the right-to-left conduction slowing and the alpha oscillation by considering the information on the luteal phase. Another limitation of the present study was that eye dominance was not assessed. Since previous research demonstrated that IHTT may vary depending on eye dominance,[51] future studies should control for this factor to provide more precise interpretations.

In conclusion, considering our preliminary findings and the limited literature, we suggest that the most likely reason for the slowness of right-to-left transmission in slow readers, which was reported in the previous article, might arise from fibers oscillating in the alpha frequency. This is the first finding concerning healthy readers showing variability in the oscillation of callosal fibers at the alpha frequency during silent word reading. Our finding regarding the alpha band in the callosal transfer speed during word reading is valuable. It refines existing models of reading by emphasizing the interplay between hemispheric specialization and interhemispheric communication. Second, understanding these dynamics could inform early interventions aimed at improving interhemispheric communication in struggling readers. Third, it contributes to the enlightenment of the neurobiological basis of reading in accordance with callosal fiber and transmission differences between subjects. Repeating the findings in individuals with dyslexia or expanding them using different methods such as transcranial magnetic stimulation and functional magnetic resonance will strengthen the findings. Additionally, future studies should explore the interplay between higher-level cognitive processes and channel-specific properties in detail. Consistent with the critical role of the corpus callosum in interhemispheric communication, structural abnormalities of this pathway have been associated with disrupted functional connectivity in several neurological conditions, such as autism, multiple sclerosis, and Alzheimer's disease. For instance, corpus callosum atrophy in Alzheimer's disease has been correlated with reduced interhemispheric coherence. Beyond its relevance to typical and impaired reading, this technique may also be applied in future research on white matter-related neurological disorders, where callosal conduction and interhemispheric communication are frequently compromised. In such conditions, latency-based IHTT estimation could serve as a noninvasive electrophysiological marker to assess interhemispheric connectivity, monitor callosal integrity, and track neuroplastic changes during language or cognitive rehabilitation.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: H.A.K.: Idea/concept, design, data collection and processing, analysis, literature review, writing the article and materials; C.K.: Idea/concept, design, analysis, writing the article, control, critical review and funding.

Conflict of Interest: The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

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