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Do the Ears Lead the Brain? Decoding the Interpreter's Cognition through EEG Insights in Simultaneous Interpreting

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Abstract

Objectives: The field of simultaneous interpreting (SI) demands exceptional cognitive skills, including rapid language switching, split attention, and robust working memory. This study aims to decode the cognitive processes underlying SI through the use of electroencephalography (EEG). By examining the brain activity of professional and novice interpreters, we seek to identify the neural correlates of the key cognitive skills involved in SI.

Methods: Utilizing a qualitative research design, the study analyzes data from three primary sources, EEG reports, videos of interpreting performances from three novice and three professional interpreters, and semi-structured interviews.

Results: The results indicate significant differences in cognitive responses between novice and professional interpreters, with professionals exhibiting stable gamma wave activity linked to effective cognitive control and auditory processing. In contrast, novice interpreters showed variable gamma patterns and performance disruptions, particularly under complex auditory conditions. The qualitative analysis revealed that professional interpreters employ strategies such as selective listening and anticipation to manage cognitive load, while novices struggle with competing auditory stimuli.

Conclusions: This research contributes to a deeper understanding of interpreter cognition, offering insights that can guide the design of effective self-practice resources tailored to the needs of interpreters at various skill levels.

Keywords: Brain activity; cognitive skill; EEG; simultaneous interpreting

هل تقود الأذن الدماغ؟ حل شيفرة إدراك المترجم من خلال التخطيط الكهربائي للدماغ في الترجمة الفورية

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ملخّص

الأهداف: تهدف هذه الدراسة، ومن خلال استخدام تخطيط الدماغ الكهربائي (EEG) للمترجمين المحترفين والمبتدئين، إلى تحديد الروابط العصبية للمهارات الإدراكية الرئيسة المشاركة في الترجمة الفورية؛ حيث يتطلب مجال الترجمة الفورية (SI) مهارات إدراكية استثنائية، بما في ذلك التبديل السريع بين اللغات، والانتباه المتوزع، والذاكرة العاملة القوية، وكما تهدف هذه الدراسة إلى فك تشفير العمليات الإدراكية الكامنة وراء الترجمة الفورية من خلال استخدام تخطيط الدماغ الكهربائي.

المنهجية: اعتمدت الدراسة على المنهج البحثي النوعي، والذي اعتمد على تحليل بيانات الدراسة من ثلاثة مصادر رئيسية: تقارير EEG ، مقاطع الفيديو لأداء الترجمة لثلاثة مترجمين مبتدئين وثلاثة مترجمين محترفين، والمقابلات شبه المعدة مسبقا لأولئك المترجمين.

النتائج: تشير نتائج الدراسة إلى وجود اختلافات كبيرة في الاستجابات الإدراكية بين المترجمين المبتدئين والمحترفين، حيث أظهر التخطيط الداماغي للمترجمين المحترفين نشاطًا مستقرًا لموجات الجاما المرتبطة بالتحكم الإدراكي الفعال والمعالجة السمعية. وفي المقابل، أظهر المترجمون المبتدئون أنماطًا غير ثابتة لموجات الجاما واضطرابات في الأداء، خاصة في ظل الظروف السمعية المعقدة. وكما كشف التحليل النوعي أن المترجمين المحترفين يستخدمون استراتيجيات مثل الاستماع الانتقائي والتوقع لإدارة العبء الإدراكي، بينما يواجه المبتدئون صعوبة في التعامل مع المحفزات السمعية المتنافسة.

الخلاصة: تسهم هذه الدراسة في تحقيق فهم أعمق لإدراك المترجمين، وتقدم لهم رؤى قد تمكنهم من تصميم مصادر التدريب الذاتي الفعالة والوجهة لتلبية احتياجات المترجمين في مستويات مهاراتية مختلفة.

الكلمات الدالة: نشاط الدماغ، المهارة الإدراكية، التخطيط الكهربائي للدماغ، الترجمة الفورية.

1. Introduction

The human brain consists of at least 86 billion cells/neurons (Azevedo et al., 2009). These brain cells process information in the form of electrical potentials and transmit it to other cells through connections called synapses. Brain activation is a condition where these brain cells process and transmit electrical potentials (a process called action potential) (Khakim & Kusrohmaniah, 2021). When one cell is activated, it will activate nearby cells, leading to synchronization between cells, which then creates a chain effect on other cells (propagation). Fluctuations in electrical potentials arise as a result of the activity of these brain cells. These fluctuations are then measured using sensors so that researchers can observe brain activity.

In relation to brain activity, electroencephalography (EEG) is a method for recording the electrical potential activity of the brain on the surface of the scalp. Brain cells essentially produce only very low electrical potentials, so the EEG measurement method can only record the electrical activity generated by a synchronized group of cells simultaneously, and is limited to the cortical area (part of the cerebrum). Most of the electrical activity that can be recorded by EEG originates from pyramidal neurons. These cells tend to have the same orientation. Technically, EEG does not record action potentials between brain cells, but rather the aggregation of electrical potentials generated from postsynaptic potentials. (Luck, 2014)

Since simultaneous interpreting (SI) is a highly complex cognitive task that requires interpreters to listen, process, and produce speech in a target language almost instantaneously, EEG is suitably applied to investigate what happens in the brain of interpreters when they conduct SI. This SI task involves a sophisticated interplay of cognitive skills, including attention, memory, and language processing, which are crucial in ensuring accurate and efficient interpretation. Despite extensive research on these processes, the precise neural mechanisms that enable interpreters to perform SI with such agility and accuracy remain largely unexplored. With the advent of advanced neuroimaging techniques, such as electroencephalography (EEG), researchers now have the tools to delve deeper into the brain's activity during SI, providing new insights into the cognitive skills underpinning this specialized form of multilingual communication.

The brain's electrical activity during SI, especially in response to auditory stimuli, provides valuable insights into the neural mechanisms that support these processes. Understanding how auditory stimulation affects brain activity in interpreters can reveal the neural dynamics that underpin successful language transfer, particularly in high-pressure interpreting scenarios. Auditory stimuli play a crucial role in the interpreting process, acting as the primary input that triggers the interpreters' cognitive and linguistic mechanisms. Then, does it mean our ears lead the brain? Research has shown that different auditory conditions can significantly influence brain activity, but the specific impact of these stimuli on the electrical patterns of interpreters’ brains during SI remains underexplored. By examining the effects of auditory stimulation on the brain's electrical activity, this study seeks to uncover how interpreters process auditory information and manage the cognitive load during interpreting tasks. Gamma (γ) waves, characterized by high-frequency brain oscillations, are closely linked to complex cognitive functions such as attention, memory integration, and language processing. These waves are believed to be essential for the coordination of neural networks during tasks requiring high cognitive demand, such as SI. Investigating the patterns of gamma waves during SI could provide deeper insights into the neural processes that facilitate the rapid and seamless transfer of information between languages. By analyzing these patterns, this research aims to identify the specific brain dynamics that distinguish expert interpreters from novices and to understand how gamma activity correlates with interpreting performance. Following that, this study has focused on three primary research questions:

1) How does auditory stimulation affect the electrical activity in the brain of interpreters during simultaneous interpreting?
2) What are the patterns of gamma (γ) waves during the simultaneous interpreting process?
3) How do both auditory stimulation and the patterns guide the decision of application features to support self-practice?

Addressing these questions will contribute to a better understanding of the cognitive and neural foundations of SI, offering implications for interpreter training and potential applications in developing cognitive enhancement tools for interpreters. This study seeks to bridge the gap between cognitive neuroscience and interpreting studies by examining the neural correlates of key cognitive functions involved in SI. By leveraging EEG technology, we aim to capture real-time brain activity patterns that correspond to the various cognitive demands placed on interpreters. Specifically, we investigate how the brain manages the simultaneous processes of comprehension in one language and production in another, exploring the dynamic neural interactions that make this possible. Understanding these underlying neural processes is crucial not only for advancing theoretical knowledge in the field of interpreting studies but also for developing practical strategies to enhance interpreter training. By identifying the specific cognitive skills that are most crucial for successful SI and how they are reflected in brain activity, this research can inform targeted training techniques to help novice interpreters develop these essential skills more effectively. Ultimately, this study contributes to the growing body of literature on cognitive processing in multilingual tasks, offering new perspectives on how the human brain navigates the complexities of SI.

2. Literature Review

2.1 Cognitive Skill

Cognitive skills refer to the mental capabilities that enable individuals to process information, solve problems, and adapt to new situations (Friederici, 2011). These skills encompass a range of functions, including attention, memory, reasoning, and processing speed. In the context of simultaneous interpreting (SI), cognitive skills play a crucial role in managing the complex and demanding nature of the task, which requires the rapid integration of auditory input and language production (Gumul, 2021; Hikmaharyanti et al, 2023). One of cognitive skills requiring much in simultaneous interpreting is working memory which is another critical cognitive skill for interpreters. Baddeley's (2000) model posits that working memory consists of multiple components, including the phonological loop and the central executive. In interpreting, the phonological loop helps retain verbal information long enough for processing and translation. Studies have shown that interpreters with higher working memory capacity tend to have better performance outcomes. For example, research by Christoffels et al. (2006) indicated that working memory capacity was positively correlated with interpreting accuracy and fluency, especially during complex tasks that required simultaneous processing of language input and output. Further, increased cognitive load can overwhelm working memory, leading to performance decrements. Research by Seeber (2015) highlighted that interpreters often experience cognitive overload in challenging conditions, resulting in diminished working memory performance, increased errors, and longer processing times. Cognitive skills are integral to the success of simultaneous interpreting. Research on attention, working memory, processing speed, and cognitive flexibility provides valuable insights into how interpreters manage the cognitive demands of their tasks. By understanding and enhancing these skills through targeted training, interpreter trainers can improve the performance and adaptability of future interpreters in high-pressure environments. This literature review highlights the need for continued exploration of cognitive skills in interpreting, especially in relation to advancements in cognitive neuroscience and technology.

2.2 EEG

Electroencephalography (EEG) is a non-invasive technique used to record electrical activity in the brain through electrodes placed on the scalp (Bell & Cuevas, 2012). It provides real-time insights into cognitive processes by measuring brainwave patterns associated with various mental activities (Sarrett et al, 2020). In the context of simultaneous interpreting (SI), EEG has emerged as a valuable tool for examining how interpreters manage cognitive load, process language, and respond to auditory stimuli. Research utilizing EEG has revealed insights into how cognitive load affects brain activity during simultaneous interpreting. Studies have shown that as cognitive load increases, specific EEG patterns emerge that reflect the interpreter's cognitive state, like research investigating gamma wave activity related to cognitive load where the increased gamma wave activity has been observed during high cognitive load situations, indicating the brain's engagement in complex cognitive processing (Tallon-Baudry et al., 1999). Further, research by Elmer et al. (2014) found that interpreters exhibited heightened gamma activity during challenging interpreting tasks, suggesting that their brains were working hard to integrate and produce language. Auditory stimulation also affects this process, the presence of extraneous auditory stimuli can further elevate cognitive load. Studies such as those by Schmidt-Kassow et al. (2010) specified that background noise or competing sounds resulted in increased theta and gamma activity, reflecting the additional cognitive effort required to filter and process relevant auditory information. In addition, research by Christoffels et al. (2006) revealed that when interpreters relied on their phonological loop to retain verbal information, specific EEG patterns, including increased gamma activity, were observed. This suggests that the brain is actively engaged in retaining and processing information in the short term. EEG studies have also explored the role of the central executive in managing cognitive resources during interpreting. Increased activity in frontal regions associated with the central executive has been linked to better performance in interpreting tasks (Kruger et al., 2017). The engagement of these areas, reflected in beta and gamma wave patterns, indicates that interpreters are actively allocating attention and resources to manage competing demands.

2.3 Simultaneous Interpreting

Simultaneous interpreting (SI) is a specialized form of interpreting where the interpreter translates speech from a source language to a target language in real time. This process requires highly developed cognitive and linguistic skills, as interpreters must listen, comprehend, and produce language concurrently. The complexity of SI poses unique challenges, making it a focal point of research in interpreting studies, cognitive psychology, and linguistics (Boos et al, 2022; Elmer et al, 2010). The cognitive demands of SI have been a significant area of exploration in the literature. Researchers have identified several critical cognitive processes involved in SI, including listening comprehension, language processing and working memory. Effective listening is crucial in SI, as interpreters must grasp the meaning of the source message quickly. Studies have shown that interpreters utilize various listening strategies to enhance comprehension, such as summarization and paraphrasing (Gile, 2009). Producing language in real time requires interpreters to have a strong command of both source and target languages. Research denotes that the pressure of simultaneous production can lead to errors, particularly in the areas of syntax and vocabulary choice (Pöchhacker, 2004). Furthermore, working memory plays a vital role in SI, as interpreters need to hold segments of speech in memory while processing new information (Koshkin et al, 2018; Yagura, 2021; López et al, 2023). Studies have shown that interpreters often utilize mnemonic strategies to aid memory retention, which can mitigate the cognitive load experienced during interpreting tasks (Christoffels et al., 2006).

Cognitive load theory provides a framework for understanding how cognitive demands affect interpreting performance. High cognitive load can result in diminished performance, leading to increased errors and omissions. Research by Gile (2009) emphasizes that interpreters must balance intrinsic load (the complexity of the source message) and extraneous load (environmental factors) to optimize performance. The interpreting environment can significantly impact cognitive load. Studies have pointed out that background noise, technological issues, and competing speech can heighten cognitive load, adversely affecting interpreters' performance (Schmidt-Kassow et al., 2010).

3. Research Methodology

The research employs a qualitative approach to explore the cognitive processes involved in simultaneous interpreting, focusing on how auditory stimulation affects interpreters' brain activity, particularly the patterns of gamma (γ) waves. The study utilizes three primary data sources: EEG reports, videos of interpreting performance, and semi-structured interviews. The EEG data, consisting of visual reports, are qualitatively analyzed using thematic and comparative analysis to identify key patterns in brain activity, with a focus on the differences between novice and professional interpreters. This analysis aims to explore how auditory inputs influence electrical activity, particularly gamma waves, during the interpreting process. The interpreting performance videos undergo content analysis, examining the quality and errors of interpreters in response to different auditory stimuli. These findings are mapped against EEG data to identify correlations between brain activity and observable performance, highlighting critical moments where gamma wave patterns align with specific interpreting behaviors. Semi-structured interviews are thematically analyzed to capture the interpreters' subjective experiences, strategies, and perceptions of how auditory stimulation affects their cognitive processes. These insights are triangulated with EEG and performance data to provide a comprehensive understanding of the cognitive challenges faced by interpreters. The integration of findings from EEG analysis, performance observation, and interview narratives guides the development of application features to support self-practice, tailored to the cognitive needs of interpreters based on the identified patterns of auditory influence on brain activity.

The participants consist of two groups: novice interpreters and professional interpreters. The novice group includes individuals with limited experience in simultaneous interpreting, specifically those with less than two years of practice. In contrast, the professional group consists of experienced interpreters with at least five years of professional practice. A total of 6 participants (3 from each group) is recruited through HPI (*Himpunan Penerjemah Indonesia*) or Association of Indonesian Translators based in Bali. Inclusion criteria ensures that all participants have a similar linguistic background, with proficiency in both the source and target languages (English (EN)-Indonesian (ID) and Indonesian (ID)-English (EN)).

The materials for this study include EEG equipment, which is used to record electrical activity in the brain during the interpreting tasks. A high-density EEG system is employed, utilizing a sufficient number of electrodes (e.g., 32) to capture detailed brainwave patterns. Pre-recorded auditory stimuli in the source language are used for interpreting tasks, with these clips varying in complexity and topic to assess the effect of cognitive load. Additionally, interpreting tasks are designed to challenge both novice and professional interpreters, incorporating real-time translation of the audio clips.

The procedure begins with placing EEG electrodes on participants' scalps according to the international 10-20 system, ensuring proper contact for accurate data collection. Participants are instructed on the procedure and the importance of remaining still and relaxed during recordings. During the interpreting task execution, participants listen to the auditory stimuli in the form of speech video and interpret them from source language into the target language (EN-ID and ID-EN) while their EEG activity is recorded. The tasks are conducted in a controlled environment to minimize distractions, and each session is video recorded for further qualitative analysis. After completing the interpreting tasks, participants engage in a semi-structured interview to gather qualitative data on their experiences, cognitive strategies used, and perceptions of the auditory stimuli. This provides insights into the cognitive processes at play during interpreting.

The qualitative data from interviews is analyzed using thematic analysis to identify recurring themes and patterns related to cognitive strategies and experiences during interpreting tasks. After that, those analysis is used to guide the features creation of *Interpreting App* application accessed on *Android*. While this study aims to provide valuable insights, it may have limitations, including the sample size, which may not be representative of all interpreters. Additionally, variability in individual cognitive abilities and interpreting experiences may affect the generalizability of findings. Potential artifacts in EEG recordings due to movement or external noise may also impact data quality.

4. Results

The results of this research provide an in-depth understanding of how auditory stimulation influences the cognitive processes of interpreters during simultaneous interpreting, with a specific focus on gamma (γ) wave activity. Analysis of the EEG data revealed distinct patterns in brain activity between novice and professional interpreters. Professionals exhibited higher gamma wave activity during complex interpreting tasks, suggesting enhanced cognitive control and sustained attention in response to auditory stimuli. In contrast, novice interpreters showed more variability in gamma wave patterns, with noticeable spikes during moments of cognitive overload or difficulty managing simultaneous listening and speaking tasks. This indicates that auditory stimulation plays a significant role in modulating cognitive load, with more experienced interpreters displaying more stable brain responses under auditory pressure.

Video analysis of interpreting performance supported these findings, showing that professional interpreters demonstrated smoother transitions, fewer pauses, and more accurate interpretations, particularly during moments of heightened gamma wave activity. In comparison, novice interpreters often exhibited hesitation, increased pauses, and errors during moments of high auditory complexity, aligning with the EEG data that pointed to cognitive strain. Notably, professional interpreters seemed to manage the incoming auditory input more effectively, allowing for a more synchronized flow of speech production and comprehension, which was directly correlated with their more consistent gamma wave patterns.

Insights from the semi-structured interviews provided a narrative that connected the EEG and performance data, highlighting the interpreters' personal experiences with auditory challenges. Professionals reported feeling more confident in handling complex auditory stimuli, attributing their success to developed strategies like anticipation and selective listening. In contrast, novices expressed difficulties in managing multiple auditory streams and maintaining focus, which often led to moments of cognitive overload, as evidenced in their EEG profiles. These accounts underscore the critical role of auditory processing skills in interpreter performance and suggest that targeted training could enhance novices' ability to regulate brain activity during interpreting.

Overall, the integration of EEG, performance, and interview data reveals that auditory stimulation significantly impacts the brain activity of interpreters, with distinct patterns emerging between novices and professionals. The findings suggest that professional interpreters have developed cognitive strategies that allow them to maintain steady gamma wave activity, thus optimizing their performance under auditory pressure. These insights guide the development of self-practice application features, such as auditory training modules, designed to help interpreters enhance their cognitive control over auditory input, ultimately bridging the skill gap between novice and professional interpreters. Additionally, the explanation regarding the EEG reports is detailed as follows:

Figure 1: Closed Eyes (novice interpreter)

The labels on the left (e.g., FP1-F3, C3-P3) represent the electrode placements according to the international 10-20 system. At the bottom, it states "1.60 Hz 15 Hz," indicating that the low-pass filter is set at 1.60 Hz, and the high-pass filter is set at 15 Hz. This configuration filters out frequencies outside this range, focusing on low to mid-frequency brain activity. The sensitivity is set at 7 µV/mm, which determines how much the EEG signal is amplified. And the time scale 30 mm/sec indicates the speed at which the data is displayed horizontally, and each vertical line likely represents 1 second. The EEG shows rhythmic activity across multiple channels with some variations in amplitude and frequency. Specific regions, like F4-C4 and C4-P4, show more pronounced activity with higher amplitude, suggesting localized brain activity.

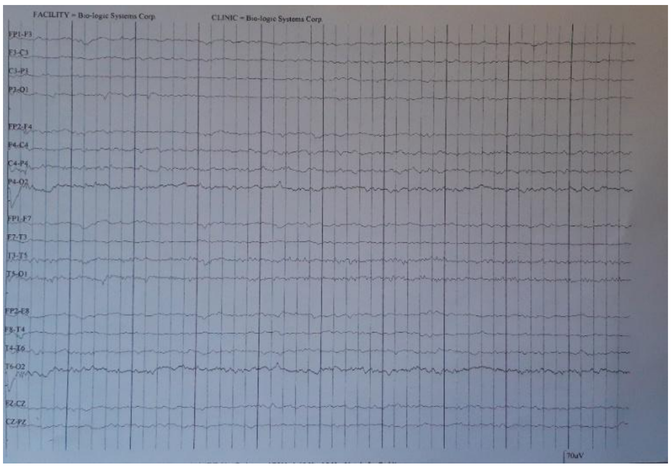

Figure 2: Closed Eyes (professional interpreter)

The report displays multiple channels labeled according to standard electrode placement (e.g., FP1-F3, F3-C3, C3-P3, etc.), which suggests this is a bipolar montage typically used in clinical EEG recording. Each channel shows the electrical activity recorded between two electrodes. The amplitude of the waveforms is relatively consistent across channels, which suggests a generally uniform level of brain activity. There does not seem to be an excessive number of high-amplitude spikes or abnormal activity like seizure discharges. The waves look relatively regular, without clear evidence of major disturbances like sharp waves, spikes, or other paroxysmal features. The rhythmic activity observed could correspond to the normal resting state or task-specific brain function, depending on the context of the recording. This is normal condition when the participant laying down while closing his eyes with no any stimulation such as light or sound.

In the context of an interpreting task, the ears and brain work together dynamically, as interpreters must perceive auditory stimuli and rapidly process and convey meaning in real time. When listening to a speaker, sound waves enter through the outer ear, where the pinna and ear canal direct the sound to the eardrum. The vibrations from the eardrum are transferred through the tiny bones in the middle ear, which amplify the sound and ensure clarity, allowing the interpreter to focus on the speaker while filtering out background noise. In the inner ear, the stapes' vibrations create waves in the cochlear fluid, stimulating hair cells that convert mechanical vibrations into electrical signals. The interpreter must distinguish between various frequencies, identifying nuances in tone and intonation that can alter meaning. These electrical signals are transmitted to the brain, where initial processing occurs, and the interpreter's brain quickly assesses the structure and content of the incoming speech, recognizing familiar phrases and determining the overall message. As signals reach the brainstem and thalamus, they are relayed to the primary auditory cortex in the temporal lobe, where the interpreter integrates auditory information with prior knowledge and contextual cues. This stage is critical, as the interpreter must rapidly retrieve relevant vocabulary and grammar to prepare for translation. Simultaneously, they must formulate a coherent response in the target language, involving language switching and managing cognitive load to avoid becoming overwhelmed. Once the interpreter has processed the incoming message, they articulate the translation almost simultaneously, coordinating auditory processing, language comprehension, and speech production. This intricate interplay between auditory perception and cognitive functioning allows interpreters to effectively manage the challenges of real-time interpretation, highlighting the complexity of their role in communication. The figure below shows how the novice interpreter obtains auditory stimuli from the speech audio and tries to interpret directly after hearing the speech.

Figure 3: Auditory stimuli (novice interpreter)

This EEG report shows brainwave activity across multiple electrode sites during a specific recording session. The figure shows the transition from a closed eyes condition to auditory stimulation. At first, the waves are not really fluctuated; then, after the sound of speech audio is played, the waves change and show different patterns.

As auditory stimuli are introduced, there is a marked increase in neural activity, particularly in the gamma frequency range, suggesting heightened cognitive engagement. The temporal channels (such as T3 and T4) exhibit distinct bursts of gamma oscillations, indicating that the brain is processing the auditory information. These changes may reflect the encoding of speech sounds and the integration of auditory signals, demonstrating the brain's responsiveness to external stimuli. Moreover, as the auditory stimuli continue, the amplitude of these gamma waves appears to increase, which may indicate enhanced attention and the active processing of the spoken content. This heightened activity could be associated with cognitive functions like memory retrieval or language comprehension, showcasing the significance of gamma wave activity in the auditory processing network. In contrast, prior to auditory stimulation, the EEG exhibits relatively stable and low-amplitude waveforms, characteristic of a resting state with closed eyes. This transition emphasizes the brain's dynamic response to auditory input and underscores the role of gamma waves in facilitating complex auditory processing and cognitive tasks, suggesting that auditory stimuli can significantly alter brainwave patterns and enhance information processing capabilities.

Figure 4: Interpreting task (novice interpreter)

In this recording, an increase in beta (13-30 Hz) and gamma (>30 Hz) wave activity is observed, which is common during complex cognitive tasks such as simultaneous interpreting. These waves indicate active information processing, heightened attention, and intensive mental activity, typically increasing when someone is focused on tasks that require sustained attention and quick responses. There is increased activity in the frontal (FP1-F3, FP2-F4) and temporal (T3-T5, T4-T6) regions, corresponding to the roles of these areas in language processing, decision-making, and cognitive control. This suggests that novice interpreters rely on frontal processes for task control. Some wave patterns appear less regular with larger-than-usual amplitudes, indicating high cognitive load or stress during simultaneous interpreting. This unstable activity may reflect the extra effort required to coordinate comprehension, processing, and language production in real-time. Parts of the recording show disturbances or artifacts that may stem from muscle movements, eye blinks, or other physical responses. These artifacts are common in active task conditions but should not be misinterpreted as pure brain activity. No pathological patterns, such as epileptiform spikes or other abnormal activities, were observed. This EEG recording reflects typical activity of a novice interpreter engaged in simultaneous interpreting, characterized by increased beta and gamma waves and dominant frontal and temporal activity.

Figure 5: Interpreting task (professional interpreter)

This EEG recording captures the brain activity of a professional interpreter during an interpreting task, with electrodes positioned according to the standard 10-20 system, covering various brain regions such as the frontal, temporal, parietal, and occipital lobes. A key feature of the recording is the use of photic stimulation at a frequency of 5 Hz, which helps evaluate the brain's response to visual stimuli, visible at the top of the chart. Some channels, particularly in the central and posterior regions like T3-T5 and T4-T6, exhibit sharp waveforms, possibly indicating transient brain activity related to cognitive processing. Occipital regions (O1, O2) display rhythmic activity that resembles alpha waves, which typically suggest a relaxed yet alert state. This rhythm might be modulated by the interpreter's mental engagement with the task. During interpreting, the frontal and temporal regions—responsible for language comprehension and production—would likely show heightened activity, potentially reflecting increased cognitive demand. Observing the interplay of brain activity in these regions could reveal insights into how interpreters process, translate, and convey information in real time.

5. Discussion

The findings of this research highlight the intricate relationship between auditory stimulation and cognitive processing in interpreters during simultaneous interpreting, emphasizing the significant differences between novice and professional interpreters. The analysis of EEG data reveals that auditory stimulation plays a crucial role in modulating the brain's electrical activity, particularly gamma (γ) waves, which are associated with cognitive control, attention, and complex problem-solving. The heightened gamma activity observed in professional interpreters suggests that they have developed advanced cognitive mechanisms to handle the demands of simultaneous interpreting, such as effective auditory filtering, sustained attention, and efficient integration of auditory input with speech production. This contrasts sharply with novice interpreters, whose variable gamma wave patterns indicate struggles with cognitive load management, especially during high-demand moments.

The video analysis further supports these neurological insights, showing that professionals exhibit smoother performance with fewer errors, pauses, and hesitations compared to novices. These behavioural differences reflect the interpreters' varying abilities to cope with auditory complexity, where professionals are able to maintain a balanced cognitive state, as evidenced by stable gamma wave activity. Novices, on the other hand, frequently encounter performance disruptions during peak cognitive demands, aligning with the EEG findings of increased variability in gamma activity. This suggests that the development of cognitive skills necessary for simultaneous interpreting, such as selective attention, working memory, and rapid information processing, significantly influences the interpreters' ability to manage auditory stimuli effectively.

Further, the semi-structured interviews provide a qualitative dimension to the data, revealing how interpreters perceive and experience the cognitive challenges associated with auditory stimulation. Professionals often reported using specific strategies, such as selective listening and predictive processing, to manage their cognitive load during interpreting tasks. These strategies appear to be key factors contributing to the stable gamma wave patterns observed in their EEG results. Novice interpreters, however, frequently described difficulties in managing competing auditory inputs and maintaining concentration, reflecting the inconsistencies in their EEG patterns. These self-reported experiences highlight the importance of cognitive strategies in managing auditory input and suggest that targeted training could be beneficial for novices.

The combined insights from EEG data, performance analysis, and interpreter narratives underscore the critical role of auditory processing skills in simultaneous interpreting. They suggest that professional interpreters' ability to maintain stable gamma wave activity is a hallmark of their cognitive expertise, allowing them to perform effectively under auditory pressure. This stability reflects a well-developed capacity to filter, prioritize, and integrate auditory information, a skill that appears to develop with experience and targeted practice. For novice interpreters, the findings suggest that variability in brain activity and performance can be addressed through specific training interventions designed to enhance auditory processing skills and cognitive control.

These results have practical implications for the development of training programs and applications aimed at supporting interpreter self-practice. By identifying the specific cognitive challenges associated with auditory stimulation, this research informs the design of application features that target the development of auditory filtering and cognitive control skills. For instance, the incorporation of auditory training modules like shadowing method that simulate real interpreting conditions could help novices build the cognitive resilience needed for professional interpreting. Overall, this study contributes to a deeper understanding of the cognitive underpinnings of simultaneous interpreting and provides a foundation for developing targeted tools to support interpreter training and skill development.

6. Conclusion

This research provides valuable insights into the cognitive processes of interpreters during simultaneous interpreting, highlighting the impact of auditory stimulation on brain activity, specifically the patterns of gamma (γ) waves. Through the qualitative analysis of EEG reports, video recordings of interpreting performances, and semi-structured interviews, the study reveals significant differences in cognitive responses between novice and professional interpreters. The stable and consistent gamma wave activity observed in professional interpreters suggests a high level of cognitive control, attention management, and effective auditory processing skills, which are essential for managing the complex demands of simultaneous interpreting. In contrast, novice interpreters exhibit more variable gamma patterns, indicating struggles with cognitive load, attention regulation, and auditory input management, which directly affect their interpreting performance.

The findings suggest that professional interpreters possess advanced cognitive strategies, such as selective listening and predictive processing, which allow them to maintain high performance under auditory pressure. Novice interpreters, however, often experience cognitive overload and performance disruptions when faced with complex auditory stimuli, highlighting the need for targeted training to enhance their auditory processing and cognitive control skills. This research underscores the critical role of auditory input in shaping interpreters' brain activity and performance, providing a basis for developing self-practice application features tailored to the cognitive needs of interpreters at different skill levels.

Overall, this study contributes to the understanding of interpreter cognition by decoding the neural and behavioral responses to auditory stimuli during simultaneous interpreting. The insights gained can guide the creation of training tools and application features that support interpreters in developing the cognitive resilience required for professional performance. By addressing the specific challenges identified in the study, such applications can help bridge the gap between novice and professional interpreters, ultimately enhancing the overall quality of interpreting practice and performance. Future research could explore the effects of different types of auditory stimuli, such as varying speech rates, accents, or background noise, on interpreters' brain activity and performance. Investigating how these factors influence gamma wave patterns and cognitive load could provide a more nuanced understanding of the specific challenges interpreters face and help tailor training modules to better simulate real-world interpreting conditions.

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