

Exploring the interaction between culture and neuroscience using event-related potential (ERP)

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Abstract: The application of the event-related potential (ERP) was almost 80 years ago and has assisted in answering many research questions. Today, ERP is considered one of the most popular techniques among other neuroscience methods. Cultural neuroscience is an emerging interdisciplinary field that applies neuroscience tools to answer research questions in culture. This paper highlights the importance of neuroscience tools, especially ERP, in advancing the new emerging interdisciplinary field of cultural neuroscience. This paper gives an overview of ERP followed by a short description and examples of the application of ERP in two recent research. Cultural study through the application of neuroscience methods such as ERP can discover and measure neural processes related to culture, which cannot be quantified by traditional pen and paper data collection. However, many more research questions need to be answered and explored in cultural neuroscience.

Keywords: Event-related potential; Cognitive processing; Cultural neuroscience; Culture

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1.0 INTRODUCTION

The research community in numerous fields has gained interest in applying neuroscience tools to observe the human brain. Electroencephalography (EEG), event-related potential (ERP), magnetoencephalography (MEG), functional magnetic resonance imaging (fMRI) and transcranial magnetic stimulation (TMS) are a few examples of neuroscience-based tools that have been used in various research. EEG/ERP is one of the most famous tools compared to the others as this tool is

entirely safe where it is non-invasive, without radioactive tracers and harmful radiation ([Allen & Kline, 2004](#); [Crosson et al., 2010](#)). Towards the end of year 1960, the application of ERP in research indicated significant growth and marked its importance ([Pubmed, 2022](#)). Based on an analysis of the PubMed database, there were a total of 171,293 published papers related to ERP, from 1946 to 2020. Over the years, there have been increasing volumes of publications pertaining to ERP (**Figure 1**).

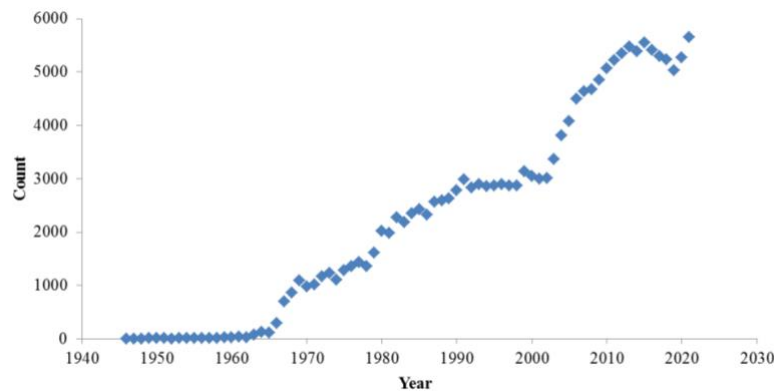


Figure 1: Number of publications per year from 1946 with ERP in the title or abstract acquired from PubMed.

The human brain is made up of approximately 80 billion neurons. Neurons make a significant number of connections with each other to form networks. This is basically how neurons in the brain communicate by transmitting information through neurochemicals and electricity. They generate this electricity through the movement of charged particles called ions. The firing rhythm of electricity produced in the brain as neurons communicate with each other can be detected over the scalp area using a tool such as EEG/ERP. Hans Berger, a neuropsychiatrist from Germany, recorded the first EEG in history. It was recorded on July 6, 1924, during a neurological operation performed by neurosurgeon Nikola Guleke, on a 17-year-old boy ([Tudor et al., 2005](#)). This historical discovery offers a new diagnostic tool for neurology and psychiatry.

Electroencephalography or EEG refers to a non-invasive tool that is competent in capturing and recording the ongoing electrical signals generated by brainwave activity, measured by placing electrode sensors over the area of the scalp ([Sebastian, 2014](#)). The electrode sensors placed on the scalp would be able to detect the brainwave activity of billions of neurons in the brain, then amplify the signals and record the brainwave pattern on a screen or graph paper. The output from EEG exhibits the electrical activity inside the brain. Therefore, ERP would be an appropriate tool to explore specific neural processes in the brain. Event-related potential or ERP, is the sequence of voltage deflection from EEG that is time-locked to a particular event, such as behavioural action or stimulus presentation ([Bradley & Keil, 2012](#)). ERP is the computed brain response in which the direct consequence of a specific cognitive, sensory or motor event ([Luck, 2005](#); [Otten & Rugg, 2005](#)). ERP can capture extremely low voltages produced inside the brain caused by a particular stimulus. The term "event-related" as ERP measures the

occurrence of a specific stimulus. The type of stimulus-of-interest measured by ERP is evoked potentials including visual, auditory, somatosensory, and olfactory ([Müller-Putz, 2020](#)). ERP is regarded as the summation of the postsynaptic potentials produced in the neural transmission process ([Schupp et al., 2006](#)). Hence, ERP is more useful in studies linked to cognitive functions such as perception, attention, emotion and memory.

The benefits of ERP include non-invasiveness, less expensive, transferable, synchronisation with the stimulus and greater validity in quantifying emotion and uncovering psychopathologies ([Allen & Kline, 2004](#)). ERP involves recording of the electrical activity generated in the brain without introduced perturbations of the cerebral regions. It is a safe method with minimum discomfort to the participant. With the latest innovation, the placement of an electrode cap that can hold hundreds of electrode sensors on the head, will result in recording at a much faster rate. Besides, ERP is widely preferred by researchers because it offers excellent temporal resolution compared to other neuroscience tools ([Voss & Paller, 2017](#)). The temporal resolution of fMRI is in seconds, whereas the temporal resolution of ERP is in milliseconds ([Zani et al., 2003](#)). This characteristic allows a temporally detailed investigation of the process underlying cognitive functions where early components reflect sensory processing and later components reflect higher-level cognitive processes ([Woodman & Luck, 2003](#)). ERP has been widely applied to explore cognitive processes as it has an excellent temporal resolution to measure neural processes precisely. For example, ERP is beneficial in research about infants, as ERP is lesser sensitive to movement artefacts. In research related to infants, the ERP technique allows enhanced comprehension of the relationship between brain and behavioural development ([Taylor & Baldeweg, 2002](#)).

As the research community come to acknowledge the impact of using the ERP technique in research, more and more researchers apply the ERP technique in clinical and non-clinical research. ERP is widely used in psychology, neuroscience, cognitive science and cognitive psychology. Many other fields unrelated to the medical field also apply neuroscience techniques in their research. For example, interdisciplinary fields include neuromarketing (neuroscience, psychology, marketing, business and consumer behaviours) ([Anuar et al., 2021](#); [Samsuri et al., 2016](#)) and neuroeducation (neuroscience, psychology, educational technology and educational theory) ([Paradis & Mercier, 2021](#); [Xu & Zhong, 2018](#)). Various fields have adopted neuroscience techniques in their study; cultural neuroscience is also an emerging interdisciplinary field that is on the rise through the application of neuroscience tools. With various fields working closely, more research questions related to culture can be answered. Research in the field of culture has an essential role as we live in a community with various cultural backgrounds. It is crucial to understand how culture affects individuals and the community.

Cultural neuroscience is a developing interdisciplinary field that combines a broad nature of the area that includes culture and social psychology, anthropology, social neuroscience and cognitive neuroscience to explore the interconnections among culture, psychological processes, brain and genes at different periods ([Chiao et al., 2013](#); [Han et al., 2013](#); [Kim & Sasaki, 2014](#); [Lin & Telzer, 2018](#)). Anthropology, cultural and social psychology study focus on what people think and behave resulting from sociocultural environments. Social and cognitive neurosciences provide theories and methods to examine the neural mechanism of social and cognitive processing ([Ochsner & Lieberman, 2001](#)). Cultural neuroscience focuses on studying sociocultural variations in mental and social processes and their representation in the brain. It aims to discover different sociocultural environment engagement influences on the brain ([Kitayama & Uskul, 2011](#)). Cultural neuroscience assists in bridging the gap between culture and neurobiological processes and therefore sheds light on better understanding on the relationship between the brain and behaviour. A pen-paper-based method such as a questionnaire might not be able to capture some aspects of culture as it happens under unconscious awareness. The self-report method would not be able to capture this information. In contrast, neuroscience tools can measure neural processes at conscious and unconscious levels.

2.0 EXAMPLES OF RESEARCH IN CULTURAL NEUROSCIENCE USING EEG/ERP

One recent study on culture used EEG/ERP to investigate cultural variances concerning social connectedness in relationship with social versus non-social assessment feedback. According to Pfabigan et al. ([2018](#)), this study found that non-social context was perceived as more significant than the social comparison context in Chinese participants. In contrast, social comparison contexts were perceived as less common and more significant than non-social contexts in Western participants. Chinese participants showed larger feedback-related negativity (FRN) amplitude modifications for non-social feedback compared to social feedback, while Western participants showed a reversed pattern. East Asian individuals view themselves as more interrelated with others, referred to as interdependent self-construal style. The processing of social comparison information in Chinese participants can be considered a default state. As individuals from interdependent cultures see themselves as interrelated with other individuals, they pay more attention to other people's behaviour ([Markus & Kitayama, 1991](#)) and routinely engage in the social comparison process on a day-to-day basis ([White & Lehman, 2005](#)). The cultural variances in brain response towards social versus non-social feedback are potentially influenced by varying cognitive characteristics ([Pfabigan et al., 2018](#)). Apart from that, another factor that could influence cultural differences in the brain response might be the experience of culturally defined behaviour to a universal extent, such as the education system. This study focuses on the function of culture in social comparison processes, which are essential for individual well-being, social communication and mental health ([Baumeister & Leary, 1995](#); [Hughes & Beer, 2013](#); [Pfabigan et al., 2018](#); [Rutledge et al., 2016](#); [Swallow & Kuiper, 1988](#)). By applying EEG/ERP, researchers can investigate neural processes among individuals of the same culture and compare them with individuals across another culture. Current research indicated a significant difference in the processing of social comparison feedback across cultures due to shared cognitive traits by individuals of the same culture. Research also found that an educational system could contribute to the differences in neural response.

Another example of a recent study was by Yusoff et al. ([2021](#)) that studied the neuro-culture interaction between the Malay ethnic, historical immigrants and present immigrants in Malaysia concerning emotional responses in the Malay cultural heritage visualisation. This study used ERP with specific culture-related stimuli

to examine the neural activity of cognitive and emotional processes. According to Yusoff et al. (2021), the result showed a significantly lower P300 and N200 amplitude in current immigrants compared to the Malay ethnic. Findings from this study sought to highlight two key aspects. Firstly, regarding the Malay culture stimulus, the results showed a similar emotional reaction between historical Immigrants and Malay ethnic. However, the first group of present immigrants who have been living for less than one year in Malaysia and the second group of present Immigrants, who have been living for more than one year in Malaysia, do not show similarity with the Malay ethnic. Secondly, concerning universal cultural stimulus, the historical immigrants and Group 2 of the present Immigrants showed similar emotional reactions to the Malay ethnic, but not Group 1 of the present Immigrants. Historical immigrants showed identical emotional responses to the Malay ethnic concerning Malay cultural stimulus due to cultural mixing or acculturation. Acculturation is a process of alteration in practices and beliefs as a cultural system of an ethnic occupied by different cultural group systems as a result of two different cultures coming across together (Berry, 2005; Padilla & Perez, 2003; Sam & Berry, 2010; Yusoff et al., 2021). Acculturation is a process whereby consistent repetition of cultural practices significantly impacts neural connectivity (Hanakawa et al., 2003; Muentz et al., 2003; Yusoff et al., 2021). While concerning universal non-cultural stimulus, the dissimilarity between Group 1 of the present immigrants and the Malay ethnic could be possible that Group 1 of the present immigrants attempted to place themselves in the Major ethnic setting and therefore overlooked the universal non-cultural stimulus in an attempt to stabilise themselves in the first phase of acculturation which is the contact phase as suggested by Pearson (1987). The approach in this cultural study by Yusoff et al. (2021) contributes to rich emotional findings. This study highlights that prolonged and temporary interaction with cultural settings significantly affects individuals' biological and psychological systems from different social-cultural backgrounds.

3.0 CONCLUSIONS

The world that we are living today is connected and interdependent. Technological progression allows people to travel frequently and quickly for various reasons, from nearby and far away to multiple places. Hence, we can see people from different cultures across locations. An increasingly multicultural world means that more interaction across individuals from various cultures and issues related to cultural diversity, such as

racism, discrimination and prejudice, could take place due to cultural differences across individuals. It is essential to learn how culture influences an individual's perception and interaction with one another to understand better and improve relationships with people from various cultures. Research in cultural neuroscience can promote a better understanding of neural mechanisms that underlie differences in psychological processes and behavior across cultures and reduce any issue that may arise due to cultural differences.

The purpose of exploring research in cultural neuroscience is to show that physical and social environments influence cultural differences in the brain. It is not to show that differences in brain activity across various cultures are hard-wired. Still, instead, it is to show that the brain is shaped by and responds to different sociocultural environments, how malleable it is in response to its surroundings (Han et al., 2013). From a social-psychological perspective, culture is interpreted as ideas, values, beliefs, and practices shared by a group (Chiao et al., 2010). It is important to explore research in cultural neuroscience further to measure the cultural constructs of interest, such as values and beliefs, which are assumed to vary across cultural groups (Han et al., 2013). Individuals from the same culture are expected to share similar cultural constructs of interest. Research in cultural neuroscience can measure the relationship between cultural construct of interest and neural activity. Estimating the association between the cultural construct of interest and neural activity allows researchers to address within and between variability shown by individuals of the same culture and individuals from different cultures. In addition, being able to distinguish culture from other concepts, such as nationality and race, is often assumed as the same, as all these three concepts share similarities.

Culture gives a united sense of belonging to an individual. This creates a sense of security and safety. Culture influences individuals and communities. Hence, more research is required to answer questions related to culture so that we can live in a harmonious and peaceful world. Two recent studies by Pfabigan et al., (2018) and Yusoff et al., (2021) highlighted above showed that cultural neuroscience has provided significant evidence that culture shapes the brain in social and emotion. In exploring the brain and culture interaction, cultural neuroscience has offered many exciting insights into the relationship between culture and the brain. However, there are further fascinating research questions that need answering and so much

more exploring in the field of cultural neuroscience that needs to be done.

Applying neuroscience tools does not only benefit operation theatre or clinical settings. The scope of application of neuroscience tools is broad and could benefit various research fields. Throughout the years, the application of ERP revealed significant findings and assisted advancement in multiple areas. Like every other method, they have their strength and limitation. However, ERP's excellent temporal resolution allows the exploration of the underlying cognitive functions in precise timing and is cost-effective compared to other neuroscience tools. Previously, most research related to culture was done through pen-paper-based methods. Instead of being self-rated by the participant, the researcher could eliminate ego and introspection from the participant by using neuroscience tools such as ERP. Therefore, data gained through the application of neuroscience tools is more valid as it reflects the actual

cognitive processing in the brain. The emerging field of cultural neuroscience assists in a deeper understanding of the causes of cultural differences, the dynamic of cultural change, and the biological foundation involved. This emerging interdisciplinary field would be able to improve knowledge of culture and guide towards implementation of better research by using neuroscience tools, especially the ERP.

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