Computers in Human Behavior 155 (2024) 108196

Contents lists available at ScienceDirect

Computers in Human Behavior

journal homepage: www.elsevier.com/locate/comphumbeh

The relationship of problematic Facebook use and Facebook context on empathy for pain processing: A functional near-infrared spectroscopy study

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ARTICLE INFO

Handling Editor: Dr. Bjorn de Koning

ABSTRACT

Positive and negative consequences of using social media (SM) have been observed. Excessive use of SM, such as Facebook, can lead to problematic behaviours, resulting in emotional and social functioning changes. Moreover, the problematic use of SM is negatively associated with empathy's affective and cognitive components. The present study used functional near-infrared spectroscopy (fNIRS) to test empathy differences between problematic and non-problematic Facebook users. In addition, the Facebook-related context that may modulate empathic response was investigated. Fifty-two participants (25 females; M_{age} = 24.6 years [SD ± 2.9]) took part in the study and were classified into two groups: non-problematic and problematic Facebook users. The study was conducted using the empathy for pain paradigm with three media-related contextual conditions: newspaper, Facebook-related, and neutral. The results indicated there was a statistically significant difference between the left and right side of the prefrontal cortex (PFC) among nonproblematic Facebook users when observing pain stimuli in the context of Facebook. For problematic Facebook users, there was significantly more activity on the left side of the PFC (compared to the right side) when observing painful stimuli in the newspaper context and non-painful stimuli in a neutral context. The differences in haemodynamic activity registered by fNIRS between the left and right PFCs were observed in both groups and may have resulted from difficulties in regulating emotional response and attention, particularly among the problematic Facebook user group.

1. Introduction

The evolution of social media (SM) has led to increasing numbers of individuals using it to communicate and exchange various content with other users (Statista, 2023). Individuals often use SM to self-present and share emotions (Kross et al., 2021). Consequently, some relationships are increasingly moving from the real world to the virtual one (Aichner et al., 2021). In this context, both the positive and negative consequences of social media use have been observed (Kross et al., 2021; Saiphoo & Vahedi, 2019). For example, SM platforms make it easy to develop supportive social contacts (Naslund et al., 2020; Sendra et al., 2020), but possible over-absorption can lead to problematic social media use for a minority of individuals (Huang, 2022; Marino et al., 2021).

2. Literature review

2.1. Problematic Facebook use

Problematic Facebook use (PFU) may be described as failing to regulate Facebook use, which leads to negative personal consequences in various domains of an individual's life, such as interpersonal conflicts, neglect of other activities, loss of control, euphoria, withdrawal, reinstatement, relapse, and salience (Elphinston & Noller, 2011; LaRose et al., 2010; Marino et al., 2018a; 2018b). However, it should also be noted that PFU has not been recognised as a clinical diagnostic unit in two major mental health disorders classifications (DSM-5; APA, 2013; ICD-11; WHO, 2018), though recent versions of these classifications have introduced diagnostic criteria for gaming disorder, which is the excessive use of electronic games.

The PFU could be considered a separate and independent disorder from problematic internet use, which may have specific characteristics related to specific psychological issues (Marino et al., 2018b). Previous research showed that PFU is associated with high psychological distress, including anxiety and depression, low life satisfaction, and low subjective well-being (Marino et al., 2018a, 2018b). Motives associated with affect regulation (e.g., reducing negative mood) and meeting internal emotional needs (e.g., need of belonging, need of admiration) may be associated with PFU (Casale & Fioravanti, 2018; Marino et al., 2018b). More specifically, Facebook users can use it when they are stressed or have difficulty dealing with the emotions they are experiencing.

It seems likely that PFU subjects use Facebook to regulate their moods, and their preference for online social interactions may lead to difficulties in reducing the scope of Facebook use (Moretta & Buodo, 2018). Consequently, one may assume that individuals' maladaptive emotional and social functioning are important for PFU development. Relatedly, empathy seems to be essential in encouraging social integration and cohesion within a community (Dalvi-Esfahani et al., 2021; Errasti et al., 2017).

Additionally, based on the Interaction of the Person-Affect-Cognition-Execution (I-PACE) model of behavioural addiction (Brand et al., 2016; 2019), one can expect that PFU individuals may be sensitive to external and internal triggers related to the addictive object, such as Facebook layout.

Facebook notification sounds, etc. It is assumed that contact with these triggers by users with PFU may lead to cue-reactivity and Facebook use craving (Brand et al., 2019; Moretta & Buodo, 2021). PFU individuals evaluated Facebook-related pictures as more positive, approach-motivated, and arousing than those without PFU (Cudo et al., 2019). Facebook-related context moderated the relationship between PFU and cognitive control (Cudo et al., 2023). Another study showed that Facebook-related context could distract participants' attention from observed painful and non-painful stimuli, which may also be linked to emotional regulation (Kopiś-Posiej et al., 2021). Considering the above, it can be assumed that the Facebook context may be an important moderator in the relationship between PFU and social functioning.

2.2. Neurophysiology of empathy for pain in the PFU context

According to the extant literature, empathy consists of both understanding and sharing the feelings and emotions of others (Decety & Ickes, 2009; Preston & de Waal, 2002). The affective (i.e., emotional responses to others' mental states) and cognitive (i.e., the cognitive ability to understand others' mental states) components of empathy contribute to individuals' functioning in the social world

(Davis, 1994; 2017). From a neurobiological perspective, this division of empathy occurs not only theoretically, but the activity of different brain regions reflects empathy's affective and cognitive aspects (Singer et al., 2004). The study by Singer et al. (2004) started a new 'empathy for pain' paradigm where the brain regions called 'pain matrix' were active while observing negative affect stimuli presenting others' pain. Although it can be assumed that empathy is a socially desirable phenomenon, e.g., in the context of activating the behavioural aspect of helping Goetz et al. (2010), the research outcomes suggest that negative affect is of greater regulatory importance (Ikes, 1997).

The negative affect has also been studied regarding constitutional underpinnings, one of which concerns brain asymmetry (Canli et al., 1998). The greater arousal of the right frontal brain regions was associated with negative affect, neuroticism, and withdrawal, whereas the left was associated with more positive affect, extraversion, and behavioural activation (Palomero-Gallagher & Amunts, 2022). Also, the prefrontal cortex activity has been recorded in studies on addictive behaviours. For example, hyperactivity of the dorsolateral prefrontal cortex (DLPFC) has been observed among individuals with internet gaming disorder (IGD), which, according to some authors, may be indicative of neural features observed in different addictive disorders (e.g., Cho et al., 2022). The activity of PFC and regions, such as the orbitofrontal cortex (OFC) and dorsolateral prefrontal cortex (DLPFC), has been investigated in previous research in an attempt to identify mechanisms of substance use disorder and gambling disorder (Dom et al., 2005; Kim et al., 2019).

3. Aim of the present study

Frequent use of social media may be linked to an attempt to regulate negative affect (Casale & Fioravanti, 2018; Marino et al., 2018b), which is important in empathy for pain. Given previous research regarding the relationship between PFU and empathy (Dalvi-Esfahani et al., 2021; Kopiś- Posiej et al., 2021; Stockdale & Coyne, 2020) and the PFC activity in the empathic process (Tullet et al., 2012), the present study aimed to investigate the differences in the PFC activity in problematic and non-problematic Facebook users in the context of empathy-related stimuli. Additionally, the stimuli were presented in a context related to Facebook, which, according to the I-PACE model (Brand et al., 2016; 2019) and a study conducted by Kopiś-Posiej et al. (2021), may influence empathic reactions. The present study had two hypotheses (H_1): the left side of the frontal cortex among participants with PFU will be more active when observing Facebook-related stimuli compared to non-PFU participants (H_2), and the PFU individuals will have lower right frontal cortex activity when observing painful stimuli in the context of Facebook compared to the non-PFU group. Activation of the prefrontal areas in the current study was measured with functional Near-Infrared Spectroscopy (fNIRS).

This neuroimaging modality has been previously applied in empathy research (Xie et al., 2018; Balconi et al., 2020a, b), but to the present authors' knowledge, not in an analogous experimental design involving the PFU issue and manipulation of the Facebook visual layout. fNIRS, though with some limitations, mainly related to the lack of subcortical structures activity monitoring, has been successfully used in studies determining the specificity of local cortical activity in response to affect-related stimuli (Balconi et al., 2009; Nishizawa et al., 2019; Rosenbaum et al., 2020; Trambaiolli et al., 2021). The presented study is partially similar to previous research applying EEG (Kopiś-Posiej et al., 2021). The demonstration of significant effects in the current investigation may, therefore, indicate that the studied processes and their determinants related to PFU are independent of neuroimaging modality, which will further strengthen the premises regarding the important role of problematic social media use in the context of pain empathy.

4. Method

4.1. Participants

Fifty-two students (25 females and 27 males; mean age = 24.63 years [SD± 2.92]) were recruited from a Polish University. All participants were right-handed and in possession of normal or corrected-to-normal vision. The respondents voluntarily agreed to participate in the study and provided their written informed consent. Based on the results of the Facebook Intrusion Scale (FIS) and FIS score norms for the Polish population (Błachnio et al., 2021), participants were divided into two groups: (i) nonproblematic Facebook use (non-PFU) group, and (ii) problematic Facebook use (PFU) group.

The Facebook Intrusion Scale (Elphinston & Noller, 2011; Przepiórka et al., 2021) was used to assess PFU. The scale consists of eight items (e.g., *"I lose track of how much I am using Facebook"*) to which the participants responded using a seven-point response scale from 1 (*strongly disagree*) to 7 (*strongly agree*). Higher scores reflect greater PFU. Based on standardised norms for FIS made for the Polish population (Błachnio et al., 2024), the participants with standard ten scores from 1 to 3 were classified as non-PFU group, and the participants with standard ten score above eight were classified as PFU group. In the study, Cronbach's alpha was 0.92. The FIS has been used to assess PFU in different countries (Błachnio et al., 2019; Przepiórka et al., 2021). The non-PFU group comprised 22 participants (15 females and 7 males; mean age=22 years [SD±2.29]; FIS score=10.95 [SD±2.28], whereas the PFU group comprised 30 participants (20 females and 10 males; mean age=23 years [SD±2.9]; FIS score=39.41 [SD±5.15]). The Facebook usage characteristics of both groups are shown in Table 1.

Table 1. Characteristics of the analysed groups.

4.2. Stimuli

The stimuli used in the study were pictures of faces taken from the Chicago Face Database (Ma et al., 2015). Selected faces (n = 20) were assessed in terms of attractiveness as average (3.8 [SD±0.7]; on a scale from 1 [very unattractive] to 5 [very attractive] (see Supplementary Materials 1). All faces were presented as pain and nonpain stimuli conditions. Non-painful stimuli comprised a cosmetic stick on the cheek of the face. Painful stimuli comprised a syringe with a needle and a drop of blood on the cheek of the face. Additionally, the present study also used newspaper and Facebook screenshots (see Supplementary Materials 2) that have been used in previous studies (i.e., Cudo et al., 2019, 2023) Facebook stimuli valence: 5.50 [SD±0.65]; arousal: 5.40 [SD±0.71]; approach-avoidance motivation dimension: 5.43 [SD±0.67]).

4.3 Procedure

Participants were informed that the experiment aimed to collect information about facial perception. Participants were required to rate the pain observed on the faces they were shown on a 1–5 scale (*"How unpleasant was this stimulus for the other person?"* from 1 [unpleasant] to 5 [not at all unpleasant]). Each trial started with a presentation of the fixation point in the middle of the computer screen for 4 seconds. Then, for 3 seconds, a face was presented, and participants gave their responses on a 1–5 scale. The study was divided into six blocks, with short breaks for participants. There were 120 stimuli divided equally into six categories, derived from two main independent variables: stimulation (painful vs. non-painful stimuli) and context (Facebook vs. neutral vs. newspaper). In each block, all possible combinations of the face's sex (female, male), context (Facebook, neutral, newspaper), and stimulation conditions (painful, non-painful) were randomly ordered for each participant.

Fig. 1. Illustration of the experimental procedure.

4.4. fNIRS acquisition and analysis

fNIRS data were recorded using Artinis Brite 24 (Elst, The Netherlands) continuous-wave functional near-infrared spectroscopy device with 24 channel montage covering forehead regions of participants' heads (see Fig. 2). The data, sampled at 25 Hz, were analysed using the Matlab 2014b with Homer3 toolbox, version 1.33.0 (Huppert et al., 2009). fNIRS data were first converted from raw intensity to optical density. Then, a temporal derivative distribution repair function was used to correct the data for motion artefacts (Fishburn et al., 2019). Bandpass filtering between 0.01 Hz and 0.3 Hz was applied, and then data were converted to haemoglobin concentration using Modified Beer- Lambert Law without partial pathlength factor correction. Segments of -2 to 12 seconds were chosen for block averaging of haemoglobin concentration data from channels: 5,6, 7, 14, 15, and 16 [left side] and 2, 3, 4, 11, 12, 13 [right side]. Only oxygenated haemoglobin data were used for statistical analysis.

Fig. 2. The channel distribution on the prefrontal cortex

5. Results

The statistical analyses were carried out using the SPSS 28 software. For the behavioural data, statistical tests were conducted for measures of pain intensity ratings as dependent variables using three-way ANOVA with repeated measures. In this analysis, the stimulus type (painful vs. nonpainful) and context (Facebook vs. neutral vs. newspaper) were within-participant factors, and the group (non-PFU vs. PFU) was between-participant factor. The assumption of sphericity was verified using Mauchly's W test (context: Mauchly's W=0.93, p=.149; context x stimulus type: Mauchly's W=0.92, p=.114). The assumption of normality was checked by visual inspection of the Q-Q plot. The homogeneity of variance between groups (non-PFU vs. PFU) in each measure was verified using Levene's test. In this context, and for all measurements, it was shown that the assumption of homogeneity of variance was met (p>.05). For the fNIRS data for oxyhaemoglobin (O2Hb), a four-way repeated measures ANOVA with the stimulus type (painful vs. non-painful), context (Facebook vs. neutral vs. newspaper), and lateralisation (right vs. left) as within-participant factors and group (non-PFU vs. PFU) as between-participant was used. The assumption of sphericity was verified using Mauchly's W test (context: Mauchly's W=0.95, p=.305; lateralisation x context: Mauchly's W=0.98, p=.569; lateralisation x stimulus type: Mauchly's W=0.98, p=.629; lateralisation x context x stimulus type: Mauchly's W=0.95, p=0.252). The assumption of normality was checked by visual inspection of the Q-Q plot. The homogeneity of variance between groups (non-PFU vs. PFU) in each measure was verified using Levene's test. In this context, for all measurements, it was shown that the assumption of homogeneity of variance was met (p>.05).

5.1 Behavioural results

A three-way ANOVA with repeated measures for the pain rating scale showed only one main effect of stimulation (F(2, 50)=85.06, p<.001, ηp^2=0.63). Painful stimuli were rated higher on the pain rating scale (2.81± 0.11, M ± SD) than non-painful stimuli (1.59 ± 0.08, M ± SD). The other main and interaction effects were statistically non-significant (p>.05).

5.2 fNIRS results

A four-way ANOVA with repeated measures showed a significant interaction between lateralisation, context, stimulation, and group: F(2, 100)=5.42, p=.006, ηp^2=0.10. In the PFU group for newspaper context in painful stimulation, there was a statistically significant difference between the left and right sides (p=.029). Pairwise comparisons showed a significant decrease of O2Hb in the right side (-1.36 [SD±2.66]) compared to the left side (0.97 [SD±2.50]) (see Fig. 3).

Fig. 3. The difference in O2Hb for painful stimulation in the problematic Facebook use group for Facebook, newspaper, neutral context, and lateralisation (left vs. right)

Also, in the PFU group for neutral context in non-painful stimulation, there was a statistically significant difference between the left and right sides (p=.001). Pairwise comparisons showed a significant decrease of O2Hb in the right side (-3.94 [SD± 2.24]) compared to the left side (0.26 [SD± 2.11]) (see Fig. 4).

Fig. 4 The difference in O2Hb for non-painful stimulation in the problematic Facebook use group for Facebook, newspaper, neutral context, and lateralisation (left vs. right)

In the non-PFU group for Facebook context in painful stimulation, there was a statistically significant difference between the left and right sides (p=.021). Pairwise comparisons showed a significant increase of O2Hb on the right side (1.49 [SD±2.52) compared to the left side (- 1.02 [SD±2.56) (see Fig. 5)

Fig. 5. The difference in O2Hb for painful stimulation in the non-problematic Facebook use group relative to Facebook, newspaper, neutral context, and lateralisation (left vs. right)

6. Discussion

The present study examined the difference between non-problematic and problematic Facebook users during their contact with stimuli associated with pain or lack of pain and their influence on the empathic reaction observed in the prefrontal cortex. The study examined whether the left side of the frontal cortex among problematic Facebook users was more active when observing Facebook-related stimuli compared to non-problematic Facebook users (H_1). In addition, the study examined whether non-problematic Facebook users had higher right frontal cortex activity when observing painful stimuli in the context of Facebook compared to problematic Facebook users (H_2). There were no significant effects for either H_1 or H_2. However, differences between the right and left sides described in the first and second research questions were significant in relation to group and context variables. According to the results, in the non-PFU group, the activation of PFC was when painful stimuli were observed in the Facebook context. The oxyhaemoglobin level was higher on the right side of PFC than on the left, which might be associated with increased activity in the right area. In contrast, in the PFU group, similar results were not observed.

The neural networks of empathy concern the activity of areas such as the medial prefrontal cortex, temporal junction, anterior insula and anterior cingulate cortex; these structures are active during the observation of painful stimuli (Fallon et al., 2020; Zaki & Ochsner, 2012). Due to the limited spatial resolution of the fNIRS, the present study only focused on the prefrontal cortex. The activation of PFC is more associated with the cognitive aspect of empathy (Fallon et al., 2020). Nevertheless, processing emotional stimuli may modulate cognitive reactions (Balconi et al., 2009) and the activity of areas such as PFC (Balconi & Molteni, 2016). Therefore, the negative affect elected by empathy-related stimuli (Ikes, 1997) may be crucial in explaining the present study's results. According to distress-relief models (Piliavin et al., 1981), individuals help other people in distress in order to relieve their own negative emotions caused by the pain of others. Therefore, individuals who experience more negative emotions may, at the same time, be more capable of sharing unpleasant feelings with others. At the same time, one motivation associated with PFU is affect regulation (Casale & Fioravanti, 2018; Marino et al., 2018b). The use of social media can affect a person's internal emotional states by allowing them to satisfy needs and reduce negative moods (Cudo et al., 2019). This may suggest that PFU may have an influence on processing negative stimuli, which are connected with empathic reactions. Observing painful stimuli on the Facebook background may moderate the negative affect in the PFU group. At the same time, in the non-problematic group, the Facebook background may attract participants' attention but without influencing painful stimuli processing.

Another possible explanation may be associated with attention capture by Facebook-related stimuli but in light of the I-PACE model (Brand et al., 2016, 2019). According to this model (Brand et al., 2016, 2019), it can be assumed that individuals with PFU may have difficulty regulating their emotional reactions to emerging stimuli. More specifically, the PFU group's attention may have been captured by elements of the Facebook layout rather than by pain-related stimuli. Abnormal PFC reactivity to cues was found to be associated with addiction-related stimuli (Goldstein & Volkow, 2011). This may be related to the differences in haemodynamic activity observed between the left and right sides of the PFC in the non-PFU group, with no corresponding relationship among those in the PFU group.

Additionally, according to approach-avoidance reactions (Noël et al., 2013), the activation of the reflective system is mediated by the prefrontal cortex (PFC), in which subcortical structures are active during impulsive reactions (Dosenbach et al., 2008; Ernst & Fudge, 2009; Ernst et al., 2013). In the case of addiction, the reflective system might not act properly, and the inhibition reactions are not controlled. For example, addicted individuals might experience prefrontal cortex dysfunction in situations requiring behavioural regulation (Bechara & Martin, 2004; Li et al., 2009). Consequently, the PFU group could have had difficulty inhibiting the reaction associated with the appearance of a Facebook-related layout that was catching their attention.

Also, an interesting result was observed for the left PFC activity among those in the PFU group when analysing painful stimuli in a neutral context and non-painful stimuli in a newspaper context. One possible explanation may be related to emotional reactivity among addicted individuals. Greater left PFC activity may be linked to emotion regulation mechanisms (Seo et al., 2014). It can be assumed that for the PFU group, the PFC haemodynamic activity may be driven by difficulty regulating their emotional reaction. In the Facebook context, the PFU group may have emotion regulation mechanisms by positive affect connected with this medium. Nevertheless, in a Newspaper and neutral context, regulating the emotional mechanisms of problematic Facebook user groups may be difficult.

6.1 Limitations

The results obtained should also be interpreted in relation to the study's limitations. The analyses were conducted with participants from Poland. Therefore, caution should be exercised in generalising the results to individuals from other cultural contexts. It should be noted that Facebook is a medium that allows the communication of text, images, or video between users and offers the possibility, among other things, to play games or broadcast events (Griffiths, 2012). Consequently, caution should be taken when generalising results to other social media platforms such as Twitter, Instagram, etc. Additionally, the PFU was assessed by a self-reported scale so that the participants may have given answers subject to bias, e.g., a lack of insight into their behaviour, a desire for social approval, etc. Despite the greater methodological reliability, studies conducted in the laboratory may have less ecological validity. Furthermore, previous research showed that PFU is associated with high psychological distress, including anxiety and depression, low life satisfaction, and low subjective well-being (Marino et al., 2018a, 2018b), which were not controlled in the study. Consequently, it is important to be aware that the presented study may simplify the situation experienced by individuals using Facebook. At last, the fNIRS technique is characterised by limited spatial resolution (1.5 centimetres) and allows the measurement of haemodynamic activity only in the places where the channel is placed (Balconi & Molteni, 2016). Therefore, the measurement was limited only to the prefrontal cortex area. Finally, examining processes that change over a relatively short period of time (i.e., emotions; Hoshi et al., 2006) may be difficult because of the slow haemodynamic response.

7. Conclusion

The present study registered significant differences in prefrontal cortex activity between individuals with and without problematic Facebook use. Also significant was the context in which the stimuli were shown to influence the empathic relationship. For the non-PFU group, painful stimuli in the Facebook context proved significant. On the other hand, for the PFU group, the newspaper-related and neutral contexts were significant for painful and non-painful stimuli, respectively. Based on the IPACE model, these results can be explained by the influence of negative and positive affect, emotional reactivity, and attention. More specifically, the PFU group may tend to allocate more attention to Facebook-related content than the non-PFU group (see Moretta & Buodo, 2021). Contact with social media-related content may also trigger a spontaneous hedonic reaction (see van Koningsbruggen et al., 2017). Consequently, it can be assumed that in the presence of Facebook-related context, Facebook layout elements may capture the attention of individuals with PFU. Therefore, stimuli related to pain may go overlooked by problematic Facebook users. In this context, it should be considered whether posting information about helping others on social media using material depicting suffering is an effective way to attract the attention of social media users, in particular, among individuals who experience problematic social media use.

Acknowledgements

We would like to thank [masked for the Reviewers] for his help in data preparation.

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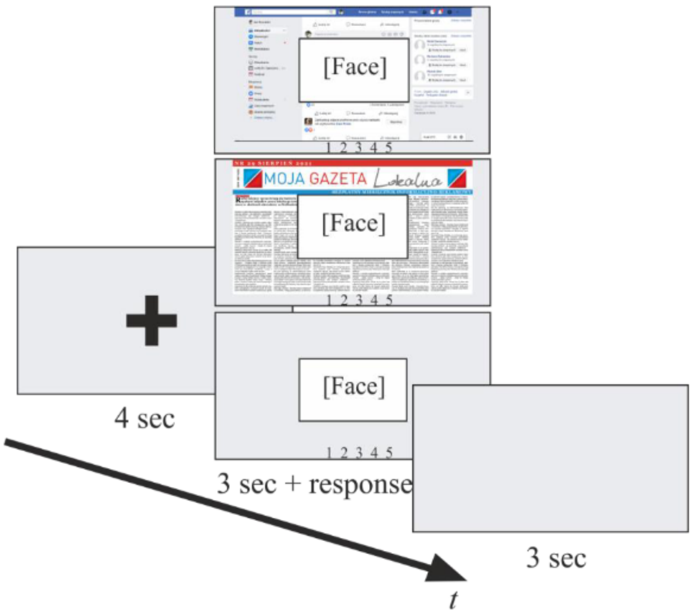
Table 1. Characteristics of the analysed groups.

Variables	Category	Non-PFU group		PFU group		χ^2	p	Cramér's V
		N	Percent	N	Percent			
Number of friends on Facebook	0-100	6	26.09%	0	0.00%	13.87	0.085	0.512
	101-200	3	13.04%	4	13.33%			
	201-300	3	13.04%	4	13.33%			
	301-400	2	8.70%	3	10.00%			
	401-500	1	4.35%	4	13.33%			
	501-600	3	13.04%	1	3.33%			
	601-700	0	0.00%	3	10.00%			
	701-800	2	8.70%	4	13.33%			
	above 800	3	13.04%	7	23.33%			

Variables	Non-PFU group		PFU group		t	p	Cohen's d
	M	SD	M	SD			
Number of hours spent per week using Facebook	5.69	6.27	17.83	13.29	4.41	0.001	1.121
Number of years of having a Facebook profile	7.42	3.89	9.83	1.93	2.74	0.005	0.823

Note: PFU = problematic Facebook use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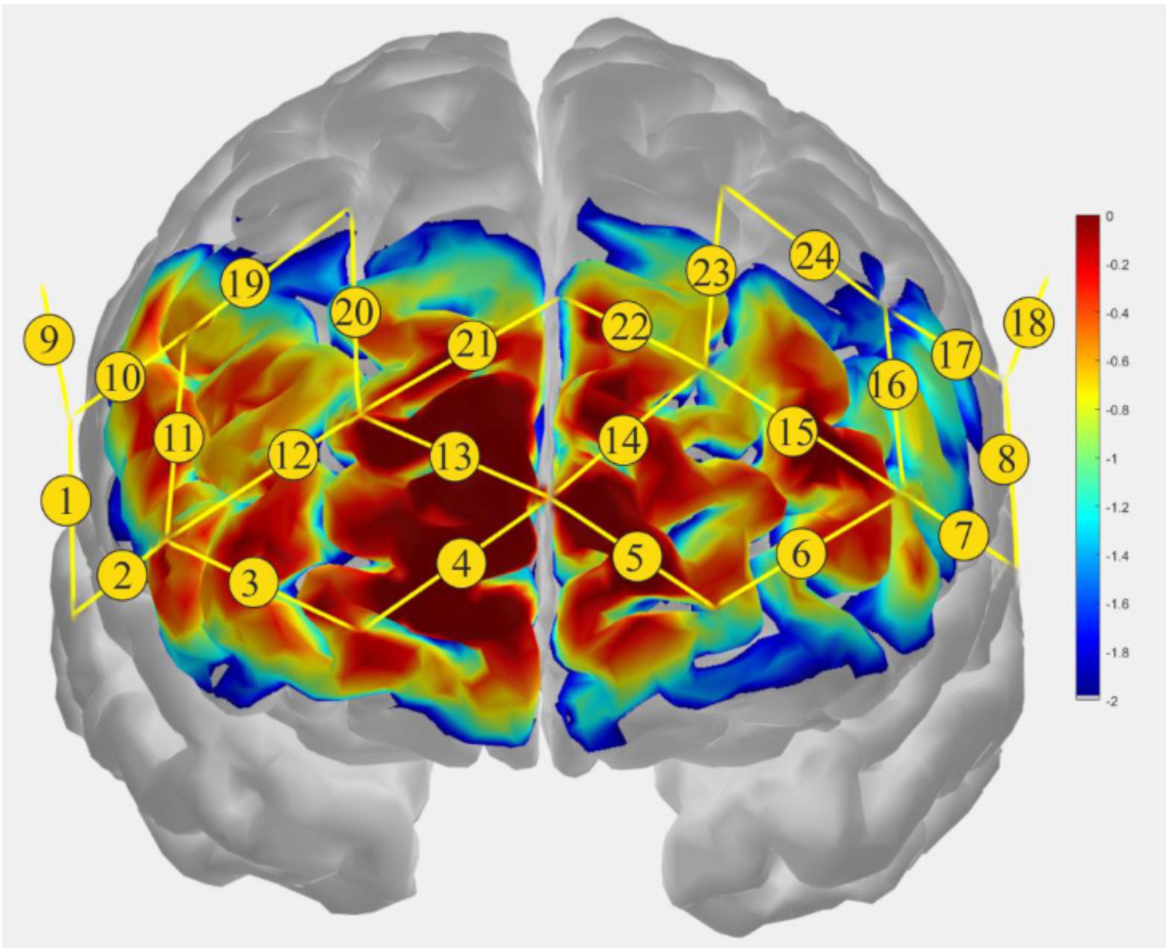
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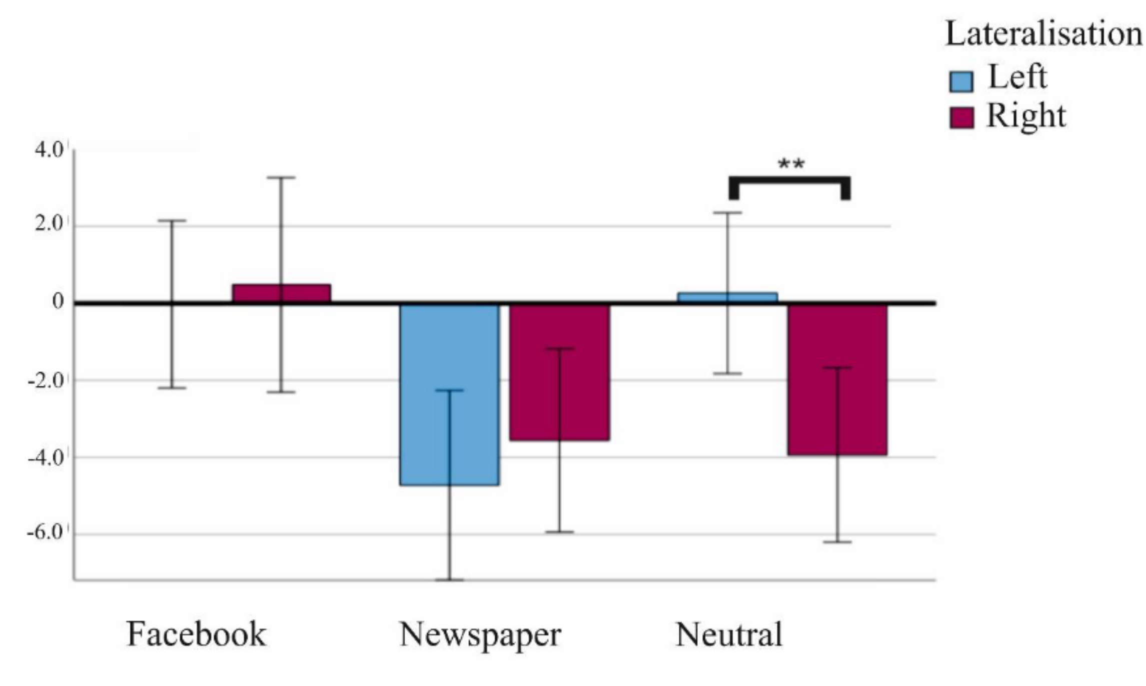
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Facebook
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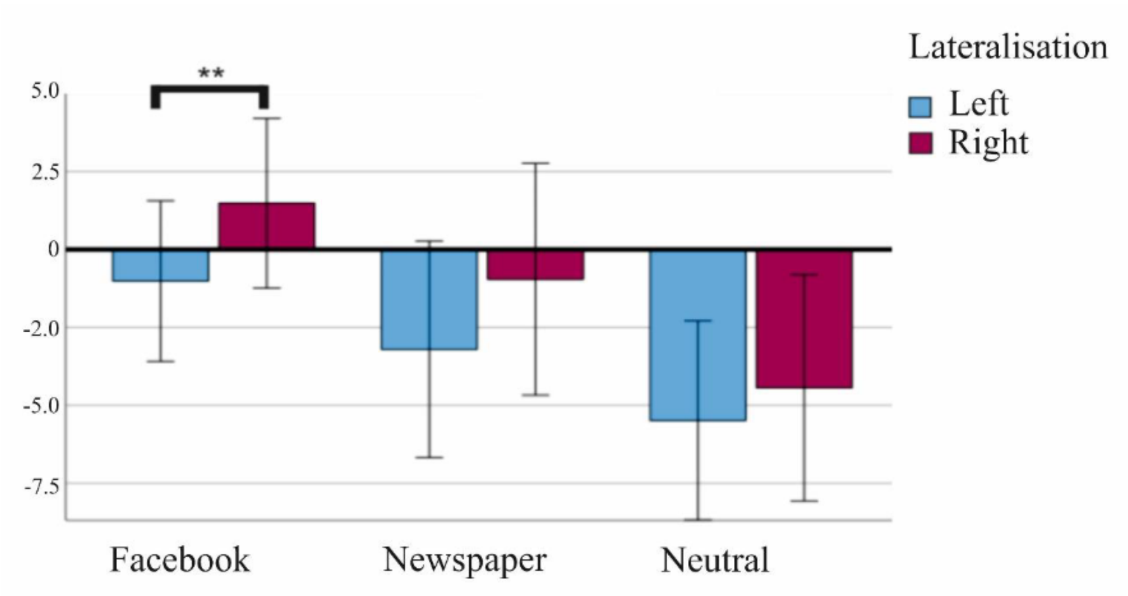
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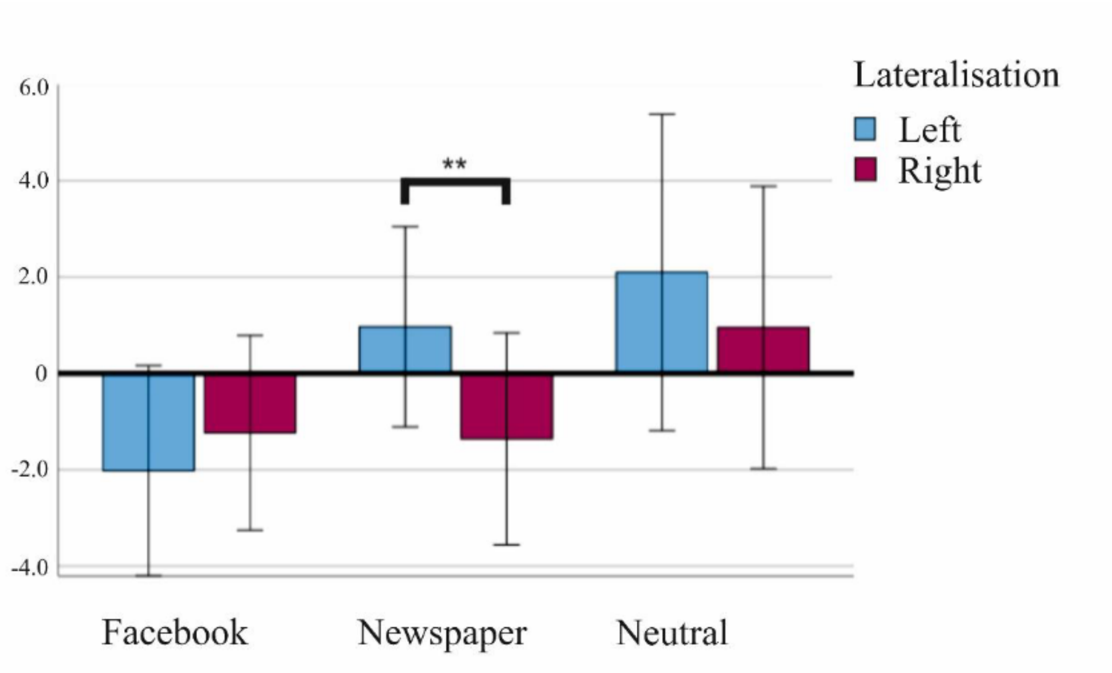

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