Connectedness and habitual use of social media predict the neural response to social exclusion in adolescents

Rui Pei1, Joseph B. Bayer2, Chris Cascio3, Matt B. O’Donnell1, Emily Falk1, Dar Meshi4

1 Annenberg School for Communication, University of Pennsylvania

2 School of Communication, The Ohio State University

3 School of Journalism and Mass Communication, University of Wisconsin-Madison

4 Department of Advertising and Public Relations, Michigan State University

Corresponding author:

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# Abstract (limit: 200 words; current 197 words)

Social media has become increasingly popular in our society. Given that social media can provide convenient means of social connection and support, research has investigated how social media may affect the way people respond to social exclusion, a common occurrence both online and offline. Yet, how social media use may be associated with neural responses to social exclusion is still largely unknown. In the current study, adolescent male Facebook users (ages 16 - 17, n = 60) reported two aspects of their Facebook use: connectedness on Facebook and habitual use of Facebook. They also completed the cyberball task, a virtual game aimed at simulating social inclusion and exclusion, while undergoing functional magnetic resonance imaging (fMRI). Findings indicated that participants who reported higher levels of connection on Facebook showed decreased neural activation in the social pain network during social exclusion. Habitual use of Facebook was associated with both higher neural activity in the mentalizing network during social exclusion, as well as lower levels of psychological distress after social exclusion. Together, these results highlight how social media usage may shift how we react to social exclusion at both psychological and neural levels, thereby protecting against the psychological distress from social exclusion.

Highlights

* Connectedness on Facebook was associated with decreased neural activation in the social pain network during social exclusion.
* Habitual use of Facebook was associated with higher neural activation in the mentalizing network during social exclusion.
* Participants who use Facebook habitually also reported less psychological distress following social exclusion.
* Social media usage may shift how people react to social exclusion at both psychological and neural levels.

Keywords

Cyberball, social Media, social exclusion, Facebook, fMRI, neural responses, distress

Acknowledgements

Funding

# 1. Introduction

Social media is now an important part of our society. Facebook, the world’s most popular social media platform, currently has 2.7 billion monthly active users worldwide [(Statistica, 2020)](https://paperpile.com/c/tAVAnX/0zyGg). A 2018 Pew Research study suggested that 97% of adolescents (13 - 17 years old) are on social media, and 51% of all adolescents use Facebook [(Pew Research Center, 2018)](https://paperpile.com/c/tAVAnX/OeEJ). Social media provide a platform for individuals to satisfy their innate drive for acquiring, building [(Meshi et al., 2015)](https://paperpile.com/c/tAVAnX/G30nf) and maintaining social connections [(Bargh & McKenna, 2004; Ellison et al., 2007; Haythornthwaite, 2005)](https://paperpile.com/c/tAVAnX/kQQMz+vo9aW+99Gr5). More broadly, social media can enhance individuals’ social networks [(Kalpidou et al., 2011)](https://paperpile.com/c/tAVAnX/rXKFg), promote stronger social ties [(Kim et al., 2016)](https://paperpile.com/c/tAVAnX/0Ne5l), help organize group activities [(Kirschner & Karpinski, 2010)](https://paperpile.com/c/tAVAnX/LSVFU), mitigate loneliness [(Meshi & Ellithorpe, 2021; Teppers et al., 2014)](https://paperpile.com/c/tAVAnX/aXqu7+GY2Ue), and offset geo-temporal differences [(Chai & Kim, 2012)](https://paperpile.com/c/tAVAnX/YNu1h). On the other hand, evidence also suggests that social media use can lead to negative affect [(Faelens et al., 2021)](https://paperpile.com/c/tAVAnX/1Y9Br), loneliness [(Hunt et al., 2018)](https://paperpile.com/c/tAVAnX/D7fWP), depression [(Primack et al., 2020)](https://paperpile.com/c/tAVAnX/yn13a), and diminished wellbeing [(Verduyn et al., 2017)](https://paperpile.com/c/tAVAnX/m5iRX). As researchers try to reconcile this conflicting evidence that social media could both benefit and harm individual’s wellbeing, there’s increasing research effort into trying to characterize different types of social media use, as well as the psychological and neural processes that might be involved in these processes.

## 1.1 Social exclusion

A growing line of research has investigated the role of social media in individuals’ responses to social exclusion [(Chiou et al., 2015; Knausenberger et al., 2015; Maner et al., 2007)](https://paperpile.com/c/tAVAnX/RN77n+D50Ml+OLPRD). A common occurrence in both offline and online interactions [(Lutz & Schneider, 2020; Sommer et al., 2020; Vorderer & Schneider, 2017)](https://paperpile.com/c/tAVAnX/MIJxU+6TMyG+N1Usi), social exclusion functions as a salient social signal [(Leary, 1990)](https://paperpile.com/c/tAVAnX/hpZGX) and constitutes a highly distressing experience that can lead to negative emotions and mental health problems, such as depression and anxiety [(Nolan et al., 2003; Prinstein & Aikins, 2004; Rigby, 2003)](https://paperpile.com/c/tAVAnX/CiWtf+CC7G1+P6ICj). At the psychological level, social exclusion can cause negative emotions such as loneliness, jealousy, depression, and anxiety [(Roy F. Baumeister & Tice, 1990; Leary, 1990; Stillman et al., 2009)](https://paperpile.com/c/tAVAnX/Y5p7T+hpZGX+gX6gw), and threaten one’s fundamental psychological needs such as self-esteem, need for belonging, control, and sense of meaningful existence [(Williams & Nida, 2011)](https://paperpile.com/c/tAVAnX/cX4Bc). After social exclusion, individuals tend to seek social contact [(Maner et al., 2007; Xu et al., 2017)](https://paperpile.com/c/tAVAnX/D50Ml+vqBTB), and are more motivated to perform in a cognitive task to help establish a connection with others [(Jamieson et al., 2010)](https://paperpile.com/c/tAVAnX/NP6dK).

## 1.2 Neural correlates of social exclusion

Researchers have conducted myriad functional neuroimaging studies using the cyberball task among other tasks to identify the neural correlates of social exclusion. Recent meta-analyses of these studies have found that social exclusion elicits neural activation in regions associated with emotion salience and regulation [(Cacioppo et al., 2013; Vijayakumar et al., 2017)](https://paperpile.com/c/tAVAnX/zDuV+1f6d). For instance, the anterior cingulate cortex (ACC) is among the regions consistently activated during exclusion, and its activation could be interpreted as deviation from expectations or the processing of salient subjective emotional experiences (Vijayakumar et al., 2017). Another region found in the meta-analyses was the orbitofrontal cortex (OFC), which is often implicated in emotion regulation [(Golkar et al., 2012)](https://paperpile.com/c/tAVAnX/X9sc).

In addition to emotional processing and regulation, social exclusion has also been found to recruit brain regions implicated in social cognition and mentalizing (i.e. understanding other’s mental state). Past studies on the neural correlates of mentalizing have documented a network of brain regions consistently activated during tasks that involve understanding the mental states of others, including the dorsomedial prefrontal cortex (DMPFC), middle medial prefrontal cortex (MMPFC), ventromedial prefrontal cortex (VMPFC), precuneus, bilateral temporoparietal junction (TPJ), and right superior temporal sulcus (RSTS) [(Dufour et al., 2013; Frith & Frith, 2006)](https://paperpile.com/c/tAVAnX/yPeO+6MUU). Studies on the neural responses to social exclusion showed that part of the brain’s network, particularly the DMPFC and precuneus, were involved in processing social exclusion [(Cacioppo et al., 2013; Vijayakumar et al., 2017)](https://paperpile.com/c/tAVAnX/zDuV+1f6d). Activation in these regions could reflect participants’ engagement of mentalizing processes aimed at trying to understand the mental states of the perpetrators (e.g. thinking of their motivations for exclusion), or adaptively regulate social behavior by processing social cues with new information regarding the current situation [(Van Overwalle & Baetens, 2009)](https://paperpile.com/c/tAVAnX/bUlgJ).

Developmentally, adolescents go through a significant amount of brain maturation that is accompanied by physical, neural, social and emotional changes. A meta-analysis of adolescents’ (ages 7 to 18) and adults’ responses to social exclusion suggests adolescents may recruit additional neural systems in responding to social exclusion compared to adults [(Vijayakumar et al., 2017)](https://paperpile.com/c/tAVAnX/zDuV). In adolescent samples, social exclusion was found to elicit neural activity in the left OFC and the VS. In addition to the reception, learning, and prediction of rewarding outcomes [(McClure et al., 2003; J. O’Doherty et al., 2004; J. P. O’Doherty et al., 2003; Pei et al., 2020)](https://paperpile.com/c/tAVAnX/F3Io+VGIw+mr89+6Sv1), the VS is also involved in the cognitive reappraisal of negative stimuli [(Doré et al., 2017; Goldin et al., 2008; Ochsner et al., 2002, 2004; van Reekum et al., 2007)](https://paperpile.com/c/tAVAnX/JL4S+WApY+IKfn+LM7e+xRkM), suggesting that the VS may also play a key role in the regulation and reappraisal of negative emotions.

## 1.3 Social media and social exclusion

Given that social exclusion threatens our fundamental needs for connection and belongingness, and that social media can be an effective tool for establishing these social connections, prior work has investigated the role of social media in situations of social exclusion or rejection. This line of work has provided consistent evidence that social media may alleviate or buffer the negative impact of social exclusion. Research in this area has most commonly employed the cyberball paradigm [(Williams & Jarvis, 2006)](https://paperpile.com/c/tAVAnX/nPU1D), where participants are excluded from a virtual ball tossing game by two other players. Participants are often led to believe that the two other players are two individuals from other sites, when in fact they are computers with pre-programmed actions.

In one early study investigating general online social interaction [(Gross, 2009)](https://paperpile.com/c/tAVAnX/LV6LW), participants first completed the cyberball task, and were then randomized to either play a solitary game or chat with a stranger through online instant messaging. Results of this study showed that participants in the instant messaging condition reported higher self-esteem and relational value than those who played a solitary game. This provided initial evidence that online social interaction could alleviate the negative effects of social exclusion. Later studies have explicitly tested the role of social media (as opposed to general online interaction) in buffering social pain. These studies showed consistent evidence that aspects of social media, such as subliminal priming with social media images [(Chiou et al., 2015; Knausenberger et al., 2015)](https://paperpile.com/c/tAVAnX/OLPRD+RN77n), and simple exposure to one’s Facebook page [(Knowles et al., 2015)](https://paperpile.com/c/tAVAnX/3CaUX) can mitigate the negative consequences of exclusion. For instance, Knausenberger and colleagues exposed participants during inclusion or exclusion from cyberball to either the Facebook icon or a control icon (Flash Player icon) at the margin of the screen. The results of this study showed that participants in the Facebook icon condition had less need for social contact after social exclusion compared to the control condition, suggesting that Facebook may restore the relational need after social exclusion. Notably, this effect was observed when most of the participants did not report noticing an icon during the study, suggesting that the conscious processing of the Facebook icon was not necessary for social need restoration after exclusion. These experimental studies provide initial evidence that social media may help alleviate the pain of social exclusion in laboratory settings, yet it is unclear whether individual differences in how people use and interact on social media can act as a protective factor and buffer the emotional distress of social exclusion.

## 1.4 Connectedness on social media

The need to belong theory [(R. F. Baumeister & Leary, 1995)](https://paperpile.com/c/tAVAnX/2IvA7) posits that people are motivated to acquire social connections and memberships to obtain optimal functioning. Drawing from the need to belong theory, social connectedness refers to the feelings of affiliation associated with belonging to a social network [(Lee et al., 2001)](https://paperpile.com/c/tAVAnX/IqFSU). Social connectedness can be measured objectively through the quantity, frequency, and quality of social contacts, it can also be measured through the perceived feeling of meaningful connection with others at an interpersonal level [(Lee et al., 2001)](https://paperpile.com/c/tAVAnX/IqFSU). Past empirical work found that social connectedness was associated with psychological and physical well-being [(Brown et al., 2003; Lee & Robbins, 1998)](https://paperpile.com/c/tAVAnX/LEqt+OJVG) and lower levels of psychological distress caused by social evaluation (Heinrichs et al., 2013). At a neural level, self-reported daily social interactions were associated with attenuated neural activation in the ACC during social exclusion (Eisenberger et al., 2007). Together, these studies highlight that offline social connectedness could serve a protective role in reducing neural and psychological responses to stressful social situations.

In addition to social connectedness in the context of traditional offline networks, individuals can also derive social connectedness through online social networks, such as Facebook networks (Grieve et al., 2013). Similar to offline social connectedness, connectedness on social media was associated with less depression, anxiety, and stress, greater levels of subjective well-being (Grieve et al., 2013), and greater levels of relational closeness with friends [(Ledbetter et al., 2011)](https://paperpile.com/c/tAVAnX/ugSF). Together, these studies suggest that social media platforms could serve as a medium through which individuals develop and maintain social relationships and connectedness, which may lead to a number of downstream benefits, such as lower levels of psychological stress caused by social exclusion.

## 1.5 Habitual use of social media

In addition to connectedness on social media, research has examined the habitual and automated use of social media. The habitual use of social media has previously been defined as the automaticity in consumption and use of the social media platform that develops as individuals repeatedly and routinely access, interact, and utilize [(LaRose, 2010; Orbell & Verplanken, 2010; Vishwanath, 2015)](https://paperpile.com/c/tAVAnX/SUm3s+eIjAt+1TrII). This definition is in line with the current thinking that habitual use of social media stems from repeated media consumption in stable circumstances [(LaRose, 2010; Verplanken & Wood, 2006)](https://paperpile.com/c/tAVAnX/SUm3s+SJGot). These repeated behaviors can over time become action-scripts that are applied with minimal conscious reflection about its antecedents, consequences, or even its enactment [(LaRose & Eastin, 2004)](https://paperpile.com/c/tAVAnX/OkwEi), which may facilitate users to meet their personal and social goals in a low-cost manner [(Seo & Ray, 2019)](https://paperpile.com/c/tAVAnX/g3iha).

Compared to offline interactions in which a person’s network often included a limited set of social contacts, social media allows individuals to manage relationships with hundreds of contacts, see people's interactions with each other, and get updates from their contacts in the form of images, videos, and texts. Given social media’s higher demand in social processing, it has been suggested that habitual social media use may involve higher levels of social cognitive processes at both behavioral and neural levels (Meshi, Morawetz, & Heekeren, 2013). For instance, a cross-sectional study linked chat-related Facebook behaviors with higher tendencies for perspective taking (Alloway, Runac, Qureshi, & Kemp, 2014). Moreover, a recent study using a longitudinal design demonstrated that Facebook use behavior improved adolescents’ perspective taking ability over time (Vossen & Valkenburg, 2016). At the brain level, higher levels of Facebook use were positively associated with greater grey matter volume in regions involved in social cognition and semantic processing (Turel, He, Brevers, & Bechara, 2018). These studies provide initial evidence that higher levels of social media use may be associated with the tendency to engage in perspective taking, as well as anatomical changes in brain regions associated with social cognition.

In addition, the automatic and habitual use of Facebook may provide a stable source for social interaction and connection with relatively low levels of cognitive efforts. Although empirical work on the potential effects of habitual social media use is still limited, a recent study suggests a potential U-shaped relationship between habitual Facebook use and psychological wellbeing, such that there was a positive association between habitual Facebook use and wellbeing at low levels of Facebook use, and a negative association at high levels of habitual Facebook use [(Islam & Patil, 2015)](https://paperpile.com/c/tAVAnX/WTbF). Results of this study provide initial evidence that habitual Facebook use can affect the wellbeing of the users.

In short, habitual social media use may involve higher levels of social cognition processes at both behavioral and neural levels. The automatic and habitual use of social media can also provide a stable, low-cost source for social interactions, thus contributing to lower levels of psychological distress after social exclusion.

## 1.6 Current study

The present study investigates the link between aspects of social media usage (connectedness on Facebook and habitual use of Facebook) and the neural response to social exclusion. In the above sections, we presented research demonstrating that connectedness in the real-world and on social media may have a buffering effect on social exclusion. In addition, mentalizing is also evoked by social exclusion, and empirical evidence supports the link between social media use and the anatomical size of brain regions involved in mentalizing. Given these considerations, we hypothesize that adolescents who report greater connectedness to family and friends on social media will demonstrate a reduced neural response to social exclusion in the social pain network (H1). Conversely, adolescents who report greater habitual use of social media will demonstrate an increased response in the mentalizing network (H2). To address these hypotheses, we collected self-report data from 66 adolescent participants. We had them fill out surveys on their Facebook use, and then perform the cyberball task while undergoing functional magnetic resonance imaging (fMRI). Participants also reported their levels of psychological distress after the cyberball task. We then ran ordinary least square (OLS) regression analyses to examine relationships between self-report and neuroimaging measures.

# 2. Methods

## 2.1 Participants

Our sample consisted of 60 adolescent males between 16 and 17 years old (Mean age = 16.87, SD age = 0.38), after excluding 6 participants due to missing self-report data, and 19 participants for missing fMRI data. Participants were recruited from high schools in [location blinded for peer review], and surrounding communities, and all reported using Facebook. This sample combined two data collection periods which were part of a larger series of studies exploring adolescent driving behavior: sample 1 (N = 22; M age = 16.85, SD age = 0.47) data were collected between July and October of 2011 (citations blinded for peer review); and sample 2 (N = 38, M age = 16.88, SD age = 0.32) data were collected between July 2012 and January 2013 (citations blinded for peer review). The two samples did not differ significantly on age (t (32.58) = -0.20, p = 0.84). All regression models below included a covariate for sample wave to account for potential unmeasured differences between the samples. Participants provided written assents and their legal guardian provided written consents in accordance with the Institutional Review Board of [institution blinded for peer review] and were compensated for their participation.

## 2.2 Cyberball task

To measure participants’ neural responses to social exclusion, participants completed the cyberball task (Figure 1) in an fMRI scanner. Cyberball has been validated in a number of behavioral and neuroimaging studies as a reliable way of simulating the experience of social exclusion – this task was found to elicit social distress and mentalizing among participants [(Masten et al., 2012; Williams & Jarvis, 2006)](https://paperpile.com/c/tAVAnX/nPU1D+J5Uia). Upon arrival at the fMRI session, participants were introduced to two gender-matched peer confederates. Participants were told that in the MRI scanner, they would be playing some games on their own, as well as in a group with the other two peer “participants” (confederates). Participants were then completed the pre-scan questionnaires as well as the fMRI tasks, and the confederates were not involved in study procedures. During the fMRI session, participants next completed a series of tasks, including a game called cyberball. In this game, participants interacted with two virtual players and tossed a ball at each other. A fair game of cyberball (i.e. the “inclusion condition”; approximately 3 minutes in length; Meannumber of throws = 83.68 , SDnumber of throws = 14.20) was always played first, in which the participant and two virtual players received the ball equally often. After a brief pause, this was followed by an unfair game (i.e. the “exclusion condition”; approximately 3 minutes in length; Meannumber of throws = 60.22, SDnumber of throws = 5.05), in which the participant was left out of ball throws, simulating exclusion. The order of the two rounds was held constant to simulate the same psychological experience across participants.

## 2.3. Self-report measures

Prior to the cyberball task in the fMRI scanner, participants’ connectedness on Facebook and habitual use of Facebook were measured through an online questionnaire. Following the cyberball task, participants reported the extent that they were threatened during the game. Each of these assessments is described below.

### 2.3.1 Facebook measures

Measures we used for connectedness on Facebook and habitual use of Facebook are detailed in Table 1. Connectedness on Facebook was measured through two items (do you feel connected with a. your family or b. your friends on Facebook?). The two items are positively correlated in the larger Facebook sample (r (83) = 0.24, p = 0.028), and an average of participants’ responses to these two items were calculated as the connectedness on Facebook score. Participants’ habitual use of Facebook was assessed through a revised version of the Self-Report Habit Index in line with past technology research (SRHI; Verplanken & Orbell, 2003; see Bayer & Campbell, 2012). Items were rated on a 7-point Likert scale from “strongly disagree” to “strongly agree”. We performed reliability analyses on the obtained data and Cronbach’s alpha demonstrated good internal consistency (α = .91). Average scores were calculated as an overall index of habitual use of Facebook. Both connectedness on Facebook and habitual use of Facebook were normally distributed in our sample.

### 2.3.2 Need threat scale

Following the cyberball task, we assessed the extent to which participants’ fundamental needs (belongingness, self-esteem, meaningful existence, control) were threatened during the game using the Need Threat Scale [(Zadro et al., 2004)](https://paperpile.com/c/tAVAnX/ZEbbd). Participants were asked to indicate on a 7-point Likert scale how much their fundamental needs were threatened for 12 need items, with each fundamental need represented by three items. Consistent with prior literature [(Gerber et al., 2017; Jamieson et al., 2010)](https://paperpile.com/c/tAVAnX/NP6dK+rp2NQ), we used an average response to the 12 items as an overall need threat score. The need threat score was normally distributed in our sample.

## 2.4 FMRI Data Acquisition and Analyses

Our imaging data from the two samples were acquired using two scanners: data from all sample 1 participants and part of sample 2 were acquired in one scanner, and the remaining sample 2 participants were acquired in a different scanner. All scans were performed on the same platform (3 Tesla GE Signa MRI) and with the same scanning parameters. Additionally, all regression models in the current analysis included a covariate for scanner ID to account for potential differences between the scanners.

Functional images were recorded using a reverse spiral sequence (TR = 2000 ms, TE = 30 ms, flip angle = 90°, 43 axial slices, FOV = 220 mm, slice thickness = 3mm; voxel size = 3.44 x 3.44 x 3.0 mm). We also acquired in-plane T1-weighted images (43 slices; slice thickness = 3 mm; voxel size = .86 x .86 x 3.0mm) and high-resolution T1-weighted images (SPGR; 124 slices; slice thickness = 1.02 x 1.02 x 1.2 mm) for use in co-registration and normalization.

Functional data were pre-processed and analyzed using Statistical Parametric Mapping (SPM8, Wellcome Department of Cognitive Neurology, Institute of Neurology, London, UK). To allow for the stabilization of the blood oxygen-level dependent (BOLD) signal, the first four volumes (eight seconds) of each run were discarded prior to analysis. Functional images were despiked using the 3dDespike program as implemented in the AFNI toolbox [(Cox, 1996)](https://paperpile.com/c/tAVAnX/9ssi2). Next, data were corrected for differences in the time of slice acquisition using interpolation; the first slice served as the reference slice. Data were then spatially realigned to the first functional image. We then co-registered the functional and structural images using a two-stage procedure. First, in-plane T1 images were registered to the mean functional image. Next, high-resolution T1 images were registered to the in-plane 16 image. After co-registration, high-resolution structural images were skull-stripped using the VBM8 toolbox for SPM8 (http://dbm.neuro.uni-jena.de/vbm), and then normalized to the skull-stripped MNI template provided by FSL. Finally, functional images were smoothed using a Gaussian kernel (8 mm FWHM).

The two rounds of the cyberball task were modeled as blocks: an inclusion block and an exclusion block. The current analysis focused on neural activation during the exclusion vs. inclusion contrast. The six rigid-body translation and rotation parameters derived from spatial realignment were included as nuisance regressors. Data were high-pass filtered with a cutoff of 128s.

## 2.5 Brain Regions of Interest (ROIs)

Analyses were conducted using two sets of *a-priori,* theory-driven regions of interest (ROIs) previously implicated in either social pain or mentalizing. First, we defined our social pain ROIs based on a prior meta-analysis of cyberball social exclusion studies in pre-adolescents and adolescents (age range 7-18 years; Figure 2a; Vijayakumar et al. 2017). The social pain ROIs included two clusters: one in the VS and one in the left OFC.

Second, given the focus of past work on mentalizing and social cognition in relation to social media use [(Achterberg et al., 2016; Baek et al., 2017; Sherman et al., 2016)](https://paperpile.com/c/tAVAnX/kkj4j+maDwE+nGVPW), we defined our mentalizing brain regions of interest (ROI) based on a prior meta-analysis of studies using a false belief task [(Dufour et al., 2013)](https://paperpile.com/c/tAVAnX/yPeO); obtained at https://saxelab.mit.edu/use-our-theory-mind-group-maps; Figure 3a). The ROIs include dorsal DMPFC, MMPFC, VMPFC, precuneus, left TPJ, right TPJ, and right STS. These ROIs were combined into a single mentalizing network. Mean neural activation in both the social pain and the mentalizing network, and their individual ROIs, was obtained for the exclusion vs. inclusion contrast using the MarsBar toolbox for SPM [(Brett et al., 2002)](https://paperpile.com/c/tAVAnX/yPQvx).

## 2.6 Linking Facebook use with self-report and neural measures

Ordinary least square (OLS) models were constructed to investigate the relationship between Facebook use, self-reported measures, and neural responses to social exclusion.

First, we constructed four OLS models to separately estimate the associations between Facebook measures and neural responses to social exclusion in both social pain and mentalizing networks. These models included age, sample wave, and scanner ID (since data were collected in two different scanners) as covariates.

*Model 1: Neural activity in social pain ROIs ~ connectedness on Facebook + age + sample wave + scanner ID,*

*Model 2: Neural activity in mentalizing ROIs ~ connectedness on Facebook + age + sample wave + scanner ID,*

*Model 3: Neural activity in social pain ROIs ~ habitual use of Facebook + age + sample wave + scanner ID,*

*Model 4: Neural activity in mentalizing ROIs ~ habitual use of Facebook + age + sample wave + scanner ID*

Second, to complement our neuroimaging analyses, we constructed two OLS models to estimate the associations between individual differences our measures of interest and self-reported need threat after the cyberball task. These models included age and sample wave as covariates.

*Model 5: need threat ~ connectedness on Facebook + age + sample wave,*

*Model 6: need threat ~ habitual use of Facebook + age + sample wave,*

# 3. Results

## 3.1 Connectedness on Facebook and habitual use of Facebook

We examined participants’ feelings of connectedness to others on Facebook and their habitual use of Facebook. With regard to connectedness on Facebook, participants reported an overall average of 2.57 (on a 5-point scale, where “3” indicated “Neither agree nor disagree”; SD = 0.79). With regard to habitual use of Facebook, participants reported an overall average of 3.33 (on a 7-point scale, where “3” indicated “Slightly disagree”; SD = 1.28). The relationship between these two measures, when controlling for age and sample wave, was not significant (b = 0.07, 95%CI = [-0.10, 0.23], p = 0.43), indicating that the habitual use of Facebook does not necessarily indicate feeling connected to family and friends on Facebook.

## 3.2 Connectedness on Facebook and neural responses to social exclusion

We investigated whether participants’ self-reported connectedness on Facebook was linked to neural responses to social exclusion in the social pain and mentalizing networks during the cyberball task. Our analysis revealed no significant association between connectedness on Facebook and overall neural activity in the social pain network in the exclusion vs. inclusion contrast (b = -0.16, 95%CI = [-0.38, 0.06], p = 0.15; Figure 2b). We next examined each region in the social pain network separately and found that connectedness on Facebook was significantly associated with neural activity in the VS during social exclusion (Table 2; Figure 2c), but not LOFC (Table 2; Figure 2d). These findings indicate that individuals who feel more connected to family and friends on Facebook have lower levels of VS response to social exclusion.

With regards to the mentalizing network, analyses indicated no significant association between connectedness on Facebook and overall neural activity in the exclusion vs. inclusion contrast (b = -0.12, 95%CI = [-0.32, 0.09], p = 0.26). We next examined each region in the mentalizing network separately and found no significant relationships with connectedness on Facebook during social exclusion (Table 3).

## 3.3 Habitual use of Facebook and neural responses to social exclusion

We also investigated whether participants’ habitual use of Facebook was linked to the neural response to social exclusion in the social pain and mentalizing networks. Our analyses of the exclusion vs. inclusion contrast indicated no significant association between habitual use of Facebook and neural activity in the overall social pain network (b = 0.01, 95%CI = [-0.12, 0.14], p = 0.88). Further, habitual use of Facebook was not significantly associated with neural activity in each region (VS and LOFC) within the social pain network during social exclusion (Table 4).

With regards to the mentalizing network, we observed a significant positive association between habitual use of Facebook and overall neural activity in the exclusion vs. inclusion contrast ((b = 0.12, 95%CI = [0.004, 0.24], p = 0.04; Figure 4b). We next examined each region in the mentalizing network separately and found that habitual use of Facebook was significantly associated with activity in the DMPFC, MMPFC, and bilateral TPJ (Table 5; Figure 4c, 4d, 4f-h). These findings indicate that individuals who report more habitual use of Facebook show greater neural activity in the mentalizing network when being socially excluded.

## 3.4 Facebook measures and psychological distress after social exclusion

To complement our fMRI findings, we conducted two OLS models to separately examine the link between our Facebook measures, connectedness on Facebook and habitual use of Facebook, and participants’ self-reported psychological distress, captured by the need threat scale, after social exclusion in the cyberball task. We observed a marginal association between connectedness on Facebook and need threat after social exclusion ((b = -0.27, 95%CI = [-0.56, 0.02], p = 0.07; Figure 5a), and a significant association between habitual use of Facebook and need threat ((b = -0.21, 95%CI = [-0.39, -0.03], p = 0.03; Figure 5b). This analysis reveals that habitual use of Facebook predicts significantly less psychological distress after social exclusion, and that connectedness on Facebook is marginally associated with less distress after social exclusion.

# 4. Discussion

In this study, we investigated if either connectedness on social media or habitual use of social media predicted adolescents’ neural responses to social exclusion. This study revealed three primary findings. First, participants who reported feeling connected on Facebook showed lower levels of neural activity in the ventral striatum, a brain region previously shown to respond to social exclusion in adolescents during cyberball social exclusion [(Vijayakumar et al., 2017)](https://paperpile.com/c/tAVAnX/zDuV). Second, participants who reported habitual use of Facebook showed higher levels of neural activity in the mentalizing network during social exclusion. Third, participants who reported habitual use of Facebook experienced lower levels of psychological distress after social exclusion. Taken together, these results showcase that individuals who report more habitual use of Facebook or who report feeling connected on Facebook show differential neural responses to social exclusion. In addition, habitual Facebook users reported lower levels of psychological distress following social exclusion.

Results of the current study showed that participants who reported feeling connected on Facebook showed less neural activity in the VS, which was previously shown to respond to social exclusion in adolescent participants [(Vijayakumar et al., 2017)](https://paperpile.com/c/tAVAnX/zDuV). This finding complements with our self-report data, which showed a marginal negative association between connectedness on Facebook and psychological distress after social exclusion. Our results are also consistent with prior findings demonstrating that adolescents who spent more time with friends showed lower levels of activation in the social pain network during social exclusion [(Masten et al., 2012)](https://paperpile.com/c/tAVAnX/J5Uia). On the other hand, individuals in more hostile social environments demonstrated higher levels of neural activation in the social pain network [(Schriber et al., 2018)](https://paperpile.com/c/tAVAnX/OKPdc), suggesting that hostile social environments may increase the cost of potentially being ostracized by the social group, therefore increasing the stress of social exclusion. Together, these findings indicate that individuals who feel connected to family and friends, or spend more time with friends, may feel more accepted by their social support group, which in turn reduces the degree to which social stressors (such as exclusion) are perceived as threatening.

Our second finding revealed that participants who reported habitual use of Facebook showed higher levels of neural activity in the mentalizing network during social exclusion. The use of fMRI can provide additional information about the neuropsychological mechanisms that may underlie the decreased distress of the habitual Facebook users. Prior neuroimaging studies on the cyberball task has found significant activation in regions in the mentalizing network, such as the precuneus (Vijayakumar et al., 2017), MPFC [(Vijayakumar et al., 2017; Wagels et al., 2017)](https://paperpile.com/c/tAVAnX/zDuV+aOfND). And activity in the mentalizing network during social exclusion has been thought to adaptively regulate social behavior by processing social cues with new information regarding the current situation [(Van Overwalle & Baetens, 2009)](https://paperpile.com/c/tAVAnX/bUlgJ). In the context of cyberball social exclusion, recruitment of the mentalizing network may reflect participants’ efforts to inference the intentions of other players for the social exclusion [(Karremans et al., 2011)](https://paperpile.com/c/tAVAnX/dDCoh). In addition, higher neural activation in the mentalizing network was associated with higher levels of social conformity, suggesting that the mentalizing network may track social cues and regulate social behavior [(Falk et al., 2014)](https://paperpile.com/c/tAVAnX/XPrGM). More broadly, this current finding contributes to results from prior studies showing that frequent social media use may be associated with both the anatomical size and functioning of the mentalizing network [(Turel et al., 2018; Vossen & Valkenburg, 2016)](https://paperpile.com/c/tAVAnX/uOAJ+gxbk). In sum, the current study reported that individuals who report more automated, habitual use of Facebook showed higher neural activation in the mentalizing network during cyberball social exclusion, suggesting that habitual Facebook users may be better at tracking social cues and inferring intentions of the other players, which may contribute to buffered psychological distress after social exclusion.

Finally, we demonstrated that individuals who report more habitual use of Facebook experienced lower levels of psychological distress after social exclusion in the cyberball task. This finding is consistent with prior work highlighting the potential role of social media in alleviating psychological distress following social exclusion or rejection [(Chiou et al., 2015; Knausenberger et al., 2015; Knowles et al., 2015)](https://paperpile.com/c/tAVAnX/OLPRD+RN77n+3CaUX). Social media platforms can offer meaningful social connection and support to the users [(Best et al., 2014; Grieve et al., 2013; Ledbetter et al., 2011)](https://paperpile.com/c/tAVAnX/R32B+ugSF+PYhd). The habitual use of social media can be a cost-efficient and stable channel through which people obtain social support, and thus may play a protective role against stressful social situations, such as social exclusion. Prior literature that investigated the role of social media in people’s response to social exclusion often implemented an experimental paradigm in which participants are exposed to a Facebook icon [(Knausenberger et al., 2015)](https://paperpile.com/c/tAVAnX/RN77n) or a Facebook page [(Knowles et al., 2015)](https://paperpile.com/c/tAVAnX/3CaUX). Although these studies provide causal evidence of the role of social media in alleviating distress from social exclusion, they do not provide information on whether natural use of social media can exacerbate or alleviate psychological distress from social exclusion. The current study adds to the prior literature and highlights more habitual use of Facebook may provide individuals with a low-cost way of building social connections and receiving social support, thereby leading to less psychological distress after social exclusion.

The results of this study indicate associations between adolescent’s Facebook use and their neural responses to social exclusion. These results should be interpreted in the context of limitations and tradeoffs in our design. First, data of this study were collected between 2011 and 2013, when Facebook was relatively more popular among adolescents (cite). Since then, a number of social media platforms with different affordances have become more widely used by adolescents (e.g. Snapchat, Tik Tok; [(Meshi et al., 2020)](https://paperpile.com/c/tAVAnX/gk6T). Thus, more research needs to be done with newer platforms. Second, the current study sample (16- to 17-year old adolescent males) was selected because it reflects the age when adolescents frequently interact on social media platforms and social media may have a particularly great influence on adolescent psychosocial development (cite). Adolescents also undergo crucial neural maturation during this time period [(Crone & Dahl, 2012; Pfeifer et al., 2011)](https://paperpile.com/c/tAVAnX/mClr+VHVP). However, focusing on this sample may limit the generalizability of our results to the broader adolescent population. Future studies that recruit samples from diverse age ranges and genders could help illuminate if findings from this study can be generalized more broadly across adolescents. Third, our study provides correlational results on the link between Facebook use and neural responses to exclusion. Future studies that utilize experiments or longitudinal design could help elucidate the causal effects of social media use on people’s psychological and neural responses to social exclusion.

Social exclusion is painful, distressing, and threatens our fundamental needs of belongingness and connection with others [(Williams, 2009)](https://paperpile.com/c/tAVAnX/yc98T). As social media is increasingly used to facilitate social interaction [(Baym et al., 2004)](https://paperpile.com/c/tAVAnX/8T1FX), it may also alter the way humans experience and respond to social exclusions. Results from the current study highlight links between adolescents’ Facebook use and their neurocognitive response to social exclusion. In addition, participants who reported more automated and habitual use of Facebook showed lower levels of psychological distress following social exclusion. Together, these results highlight the potential role of social media in protecting against the psychological distress from social exclusion. As social media provides convenient means of social connection and support, its usage may potentially shift how we react to social exclusion at both psychological and neural levels, thereby alleviating the perceived distress of social exclusion.

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# Figures

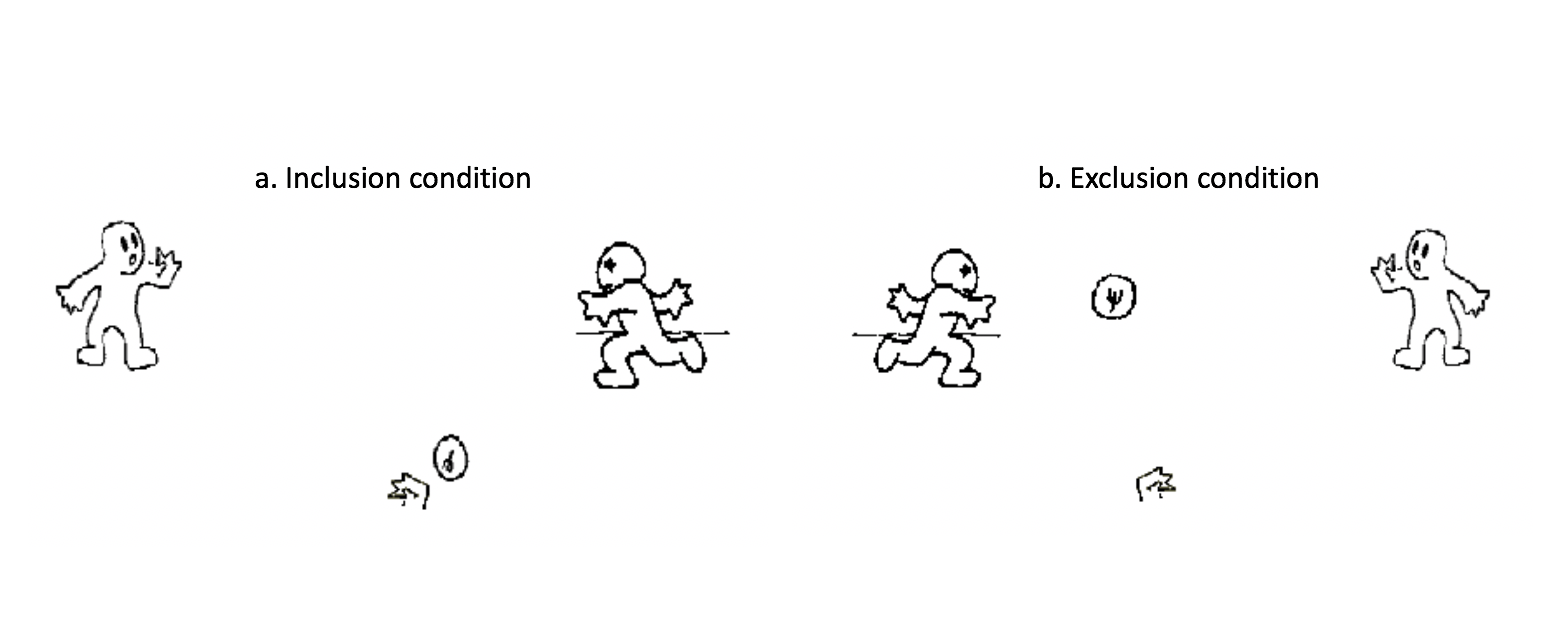


Figure 1. The cyberball task. Participants were represented by a cartoon hand at the bottom of the screen, with computerised characters (that participants believed to be peers) on either side. (a) The inclusion condition was always played first. In the inclusion condition, the participant and two virtual players received the ball equally often. (b) In the exclusion condition that followed the inclusion condition, the participant was left out of ball throws, simulating exclusion.

Chart

Description automatically generated

Figure 2. Regions of interests in the social pain network (a), and Ordinary Least Square model results linking connectedness on Facebook and participants’ neural activation in the social pain network (b) as well as its subregions (c-d) during social exclusion in the cyberball task.

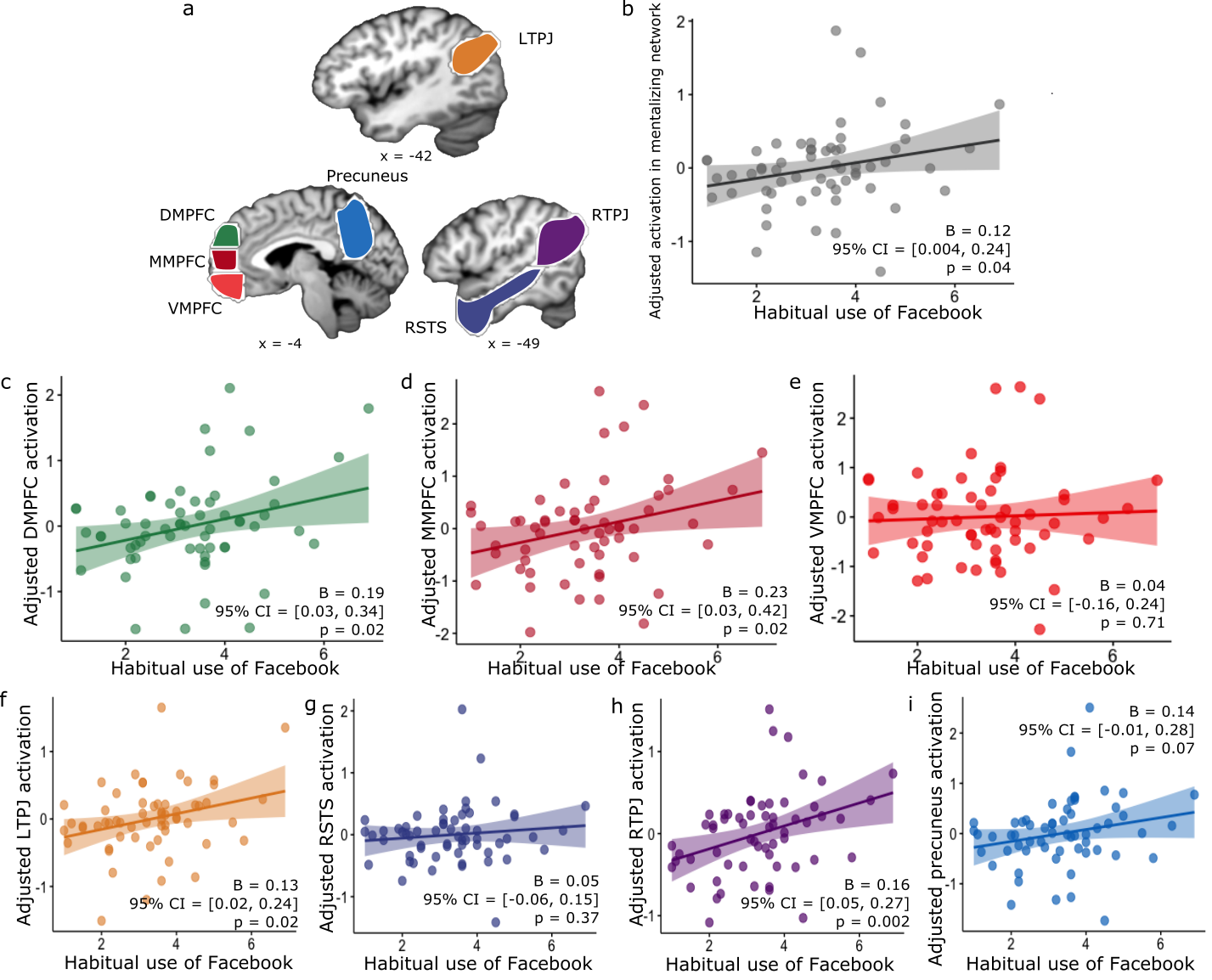


Figure 4. Regions of interests in the mentalizing network (a), and Ordinary Least Square model results linking habitual use of Facebook and participants’ neural activation in the mentalizing network (b) as well as its subregions (c-i) during social exclusion in the cyberball task.

Chart, scatter chart

Description automatically generated

Figure 5. Ordinary Least Square model results linking Facebook measures (a: connectedness on Facebook; b: habitual use of Facebook) and participants’ self-report rating of psychological distress after cyberball social exclusion.

Tables

Table 1. Self-report questionnaires for connectedness on Facebook and habitual use of Facebook.

|  |
| --- |
| **Connectedness on Facebook scale** (rated on a five-point scale)   1. I feel connected to my friends when I use Facebook. 2. I feel connected to my family members when I use Facebook. |
| **Habitual Use of Facebook Scale** (rated on a seven-point scale; [(Bayer & Campbell, 2012; Verplanken & Orbell, 2003)](https://paperpile.com/c/tAVAnX/WVwn3+kIAoH)   1. Using Facebook is something I do automatically. 2. Using Facebook is something I do without meaning to do it. 3. Using Facebook is something I do without thinking. 4. Using Facebook is something I start doing before I realize I'm doing it. 5. Using Facebook is something that would require effort not to do it. 6. Using Facebook is something I do without having to consciously remember. 7. Using Facebook is something that belongs to my daily routine. 8. Using Facebook is something I would find hard not to do. 9. Using Facebook is something I have no need to think about doing. 10. Using Facebook is something that's typically "me". |

Table 2. Ordinary least square model results of linking connectedness on Facebook and neural activation in each social pain ROI during cyberball social exclusion, controlling for sample wave, scanner ID, and age.

|  |  |  |
| --- | --- | --- |
|  | VS | LOFC |
| (Intercept) | 2.10 | 2.00 |
|  | [-5.16, 9.36] | [-6.33, 10.33] |
| Connectedness on Facebook | -0.23\* | -0.09 |
| [-0.46, -0.01] | [-0.35, 0.17] |
| Sample wave | -0.44 | -0.40 |
| [-0.92, 0.04] | [-0.95, 0.15] |
| Scanner ID | 0.20 | 0.30 |
| [-0.26, 0.66] | [-0.22, 0.83] |
| Age | -0.07 | -0.08 |
| [-0.49, 0.36] | [-0.57, 0.41] |
| R2 | 0.10 | 0.04 |
| *Note*. Numbers in brackets indicate 95% confidence interval.  \*\*\* p < 0.001; \*\* p < 0.01; \* p < 0.05. | | |

Table 3. Ordinary least square model results of linking connectedness on Facebook and neural activation in each mentalizing ROI during cyberball social exclusion, controlling for sample wave, scanner ID, and age.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | DMPFC | MMPFC | VMPFC | Precuneus | LTPJ | RTPJ | RSTS |
| (Intercept) | 3.29 | 6.72 | 4.77 | 0.38 | 1.44 | 2.51 | 1.43 |
|  | [-5.34, 11.92] | [-4.33, 17.78] | [-6.21, 15.75] | [-7.95, 8.70] | [-4.85, 7.73] | [-3.68, 8.71] | [-4.17, 7.04] |
| Connectedness on Facebook | -0.18 | -0.18 | -0.21 | -0.10 | -0.08 | -0.11 | -0.12 |
| [-0.45, 0.08] | [-0.52, 0.17] | [-0.55, 0.14] | [-0.36, 0.16] | [-0.27, 0.12] | [-0.30, 0.09] | [-0.30, 0.05] |
| Sample wave | 0.17 | 0.41 | 0.17 | 0.43 | 0.20 | 0.27 | 0.11 |
| [-0.41, 0.74] | [-0.32, 1.14] | [-0.56, 0.90] | [-0.12, 0.99] | [-0.21, 0.62] | [-0.14, 0.68] | [-0.27, 0.48] |
| Scanner ID | -0.13 | -0.34 | -0.04 | -0.16 | 0.04 | -0.17 | -0.07 |
| [-0.67, 0.42] | [-1.03, 0.36] | [-0.74, 0.65] | [-0.69, 0.36] | [-0.35, 0.44] | [-0.56, 0.23] | [-0.43, 0.28] |
| Age | -0.15 | -0.35 | -0.24 | -0.02 | -0.08 | -0.13 | -0.06 |
| [-0.65, 0.36] | [-1.00, 0.30] | [-0.89, 0.40] | [-0.51, 0.46] | [-0.45, 0.29] | [-0.50, 0.23] | [-0.39, 0.27] |
| R2 | 0.07 | 0.09 | 0.06 | 0.09 | 0.07 | 0.10 | 0.07 |
| *Note*. Numbers in brackets indicate 95% confidence interval. \*\*\* p < 0.001; \*\* p < 0.01; \* p < 0.05. | | | | | | | |

Table 4. Ordinary least square model results of linking habitual use of Facebook and neural activation in each social pain ROI during cyberball social exclusion, controlling for sample wave, scanner ID, and age.

|  |  |  |
| --- | --- | --- |
|  | VS | LOFC |
| (Intercept) | 1.63 | 0.44 |
|  | [-6.27, 9.53] | [-8.31, 9.18] |
| Habitual use of Facebook | -0.04 | 0.06 |
| [-0.18, 0.10] | [-0.10, 0.21] |
| Sample wave | -0.24 | -0.27 |
| [-0.70, 0.21] | [-0.78, 0.23] |
| Scanner ID | 0.03 | 0.20 |
| [-0.41, 0.48] | [-0.29, 0.69] |
| Age | -0.07 | -0.02 |
| [-0.53, 0.39] | [-0.52, 0.49] |
| R2 | 0.03 | 0.04 |
| *Note*. Numbers in brackets indicate 95% confidence interval.  \*\*\* p < 0.001; \*\* p < 0.01; \* p < 0.05. | | |

Table 5. Ordinary least square model results of linking habitual use of Facebook and neural activation in each mentalizing ROI during cyberball social exclusion, controlling for sample wave, scanner ID, and age.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | DMPFC | MMPFC | VMPFC | Precuneus | LTPJ | RTPJ | RSTS |
| (Intercept) | -1.32 | 1.31 | 2.93 | -2.80 | -1.56 | -1.19 | -0.12 |
|  | [-10.08, 7.44] | [-9.88, 12.49] | [-8.75, 14.61] | [-11.34, 5.74] | [-7.89, 4.76] | [-7.29, 4.91] | [-6.08, 5.83] |
| Habitual use of Facebook | 0.19 \* | 0.23 \* | 0.04 | 0.14 | 0.13 \* | 0.16 \*\* | 0.05 |
| [0.03, 0.34] | [0.03, 0.42] | [-0.16, 0.24] | [-0.01, 0.28] | [0.02, 0.24] | [0.05, 0.27] | [-0.06, 0.15] |
| Sample wave | 0.48 | 0.75 \* | 0.40 | 0.63 \* | 0.38 \* | 0.49 \*\* | 0.26 |
| [-0.02, 0.99] | [0.11, 1.39] | [-0.27, 1.07] | [0.14, 1.12] | [0.01, 0.74] | [0.14, 0.84] | [-0.08, 0.60] |
| Scanner ID | -0.39 | -0.62 | -0.23 | -0.33 | -0.10 | -0.35 \* | -0.20 |
| [-0.88, 0.10] | [-1.25, 0.01] | [-0.89, 0.42] | [-0.81, 0.15] | [-0.45, 0.26] | [-0.69, -0.01] | [-0.53, 0.14] |
| Age | 0.06 | -0.11 | -0.18 | 0.12 | 0.06 | 0.03 | 0.00 |
| [-0.45, 0.57] | [-0.76, 0.54] | [-0.86, 0.50] | [-0.38, 0.62] | [-0.31, 0.42] | [-0.32, 0.39] | [-0.34, 0.35] |
| R2 | 0.13 | 0.16 | 0.03 | 0.13 | 0.15 | 0.21 | 0.05 |
| *Note*. Numbers in brackets indicate 95% confidence interval. \*\*\* p < 0.001; \*\* p < 0.01; \* p < 0.05. | | | | | | | |