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

2. Methods

2.1 Participants

Participants included 66 adolescent males 16 or 17 years old (Mean age = 16.87, SD age = 0.38) who reported using Facebook and agreed to contribute their Facebook data. 9 participants were excluded due to missing age variable, resulting in 59 participants included in the current study. Participants were recruited from high schools in Ann Arbor, Michigan, and surrounding communities. This sample combined two data collection periods which were part of a larger series of studies exploring adolescent driving behavior: sample 1 (N = 23; M age = 16.85, SD age = 0.46) data were collected between July and October of 2011 (citations blinded for peer review); and sample 2 (N = 36, M age = 16.89, 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 (36.11) = -0.36, p = 0.72). 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 game

To measure participants’ neural responses to social exclusion, participants completed the Cyberball task 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, and was found to elicit social distress and mentalizing among the participants (Eisenberger, 2012; Williams & Jarvis, 2006; Figure 1). In this game, participants interacted with two virtual players and tossed a ball at each other. A fair game of Cyberball (3 minutes in length) 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 (3 minutes in length), in which the participant was left 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 fMRI session, participants’ Facebook connectedness and habitual Facebook use were measured through an online questionnaire. Following the Cyberball game, participants reported the extent that their fundamental needs were threatened during the Cyberball game. Each of these assessments is described below.

2.3.1 Facebook measures

Measures we used for Facebook connectedness and habitual Facebook use were included in Table 1. Facebook connected was measured through two questions, and an average of participants’ responses to these two items were calculated as the Facebook connectedness score. Participants’ habitual Facebook use 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 = .90). Average scores were calculated as an overall index of habitual Facebook use. Both Facebook connectedness and habitual Facebook use score were normally distributed in our sample.

In addition to quantitative measures of habitual Facebook use and Facebook connected, we also included an open-ended question in our survey that asked participants to “In two or three sentences please describe how you use Facebook.”

2.3.2 Need threat scale

Following the Cyberball game, we assessed the extent to which participants’ fundamental needs (belongingness, self-esteem, meaningful existence, control) were threatened during the Cyberball game using the Need Threat Scale (Zadro et al. 2004). Participants were asked to indicate on a seven-point Likert scale how much their fundamental needs were threatened for 12 need items, with each fundamental need represented by 3 items. Consistent with prior literature (Jamieson, Harkins, & Williams, 2010; Gerber, Chang, & Reimel, 2017), 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 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). 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 1c; Vijayakumar et al. 2017). The social pain ROIs included two clusters: one in ventral striatum (VS) and one in the left lateral orbitofrontal cortex (lOFC). Although prior literature has often thought that neural correlates of social rejection may overlap with those of physical pain, including the dorsal anterior cingulate cortex (dACC) and insula (Eisenberger, 2012), more recent meta-analysis of fMRI studies provided minimal evidence for dACC, and instead suggested the role of orbitofrontal cortex (Vijayakumar et al., 2017; Cacioppo et al., 2013). Additionally, recent meta-analysis that compared neural correlates of social exclusion in adolescent and young adult samples showed differential patterns of neural engagement between these two population (Vijayakumar et al., 2017). As the current study is focused on adolescent participants, the social pain network in our study was defined using the meta0analysis of Cyberball studies in adolescent samples.

Second, given the focus of past work on mentalizing and social cognition in relation to social media use (Baek et al., 2017; Sherman et al., 2016; Achterberg et al., 2016; ), we defined our mentalizing brain regions of interest (ROI) based on a prior meta-analysis of studies using a false belief task (Figure 1d; Dufour et al., 2013; obtained at https://saxelab.mit.edu/use-our-theory-mind-group-maps; Figure 1a). The ROIs include medial prefrontal cortex (MPFC), precuneus, left temporal parietal junction (LTPJ), right temporal parietal junction (RTPJ), and right anterior superior temporal sulcus (rSTS). These ROIs were combined into a single mentalizing network. Mean neural activation in both the social pain ROIs and the mentalizing network in the Cyberball exclusion vs. inclusion contrast was obtained using the MarsBar toolbox for SPM (Brett et al., 2002).

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 Cyberball social exclusion. All OLS models include age, sample wave, and scanner ID (since data were collected in two different scanners) as covariates.

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:

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

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

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

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

In addition to examining each system (social pain and mentalizing) as a whole, we conducted additional exploratory analyses to investigate whether Facebook use is associated with neural activity in each brain region within the system during the Cyberball task.

Second, to complement neuroimaging analysis, we constructed two OLS models to estimate the associations between individual differences in Facebook measures (Facebook connectedness and habitual Facebook use) and self-reported need threat after Cyberball game:

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

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

3. Results

3.1 Facebook use measures

Participants reported overall slight disagreement to the statements that they felt connected to family and friends on Facebook (M = 2.60, SD = 0.78 on a 5-point scale, where “3” indicated “Neither agree nor disagree”). Participants also slightly disagreed to the statements that Facebook is something they would use automatically and without thinking (M = 3.35, SD = 1.29 on a 7-point scale, where “3” indicated “Slightly disagree”). After controlling for age and sample wave, we found no significant association between habitual Facebook use and Facebook connectedness (beta = 0.06, 95% CI [-0.11, 0.22], p = 0.48), indicating that the habitual and automatic use of Facebook does not necessarily indicate feeling connected to family and Friends on Facebook. We examined participants’ qualitative feedback in relation to their reported Facebook connectedness and habitual use. For participants that reported feeling connected on Facebook, participants mentioned the times of day they usually use Facebook (“morning”, “evening”), the geographical location of people they contact with (“India”, “Spain”, “France”), and the frequency (“weekly”, “occasionally”). For participants that reported habitual and automatic use of Facebook, they described their Facebook use in terms of what they may use it for (“pictures”, “social”, “news”, “chat”, “share”, “videos”, “network”, etc), how they feel about it (“interesting”, “bored”, “overuse”). See Figure 1 for word clouds of frequently used words in participants who reported high levels of Facebook connectedness vs. habitual Facebook use.

3.2 Facebook connectedness and neural responses to social exclusion

We investigated whether participants’ self-reported Facebook connectedness was linked to neural responses to social exclusion in the social pain and mentalizing networks in the Cyberball task. Our data suggested no significant association between Facebook connectedness and neural activity in the social pain network (B = -0.19, 95% CI = [-0.43, 0.05], p = 0.12). We conducted further exploratory analyses that separately examined each region in the social pain network, and found that Facebook connectedness was significantly associated with neural activity in the VS (B = -0.25, 95% CI = [-0.50, -0.01], p = 0.04; Figure 2a), but not LOFC (B = -0.13, 95% CI = [-0.40, 0.15], p = 0.36; Figure 2b). These findings indicated that individuals that feel more connected on Facebook showed less VS neural response to social exclusion.

With regards to the mentalizing network, analyses indicated no significant association between Facebook connectedness and neural activity in the mentalizing network in the Cyberball exclusion vs. inclusion contrast (B = -0.13 95% CI = [-0.35, 0.09], p = 0.25). Further, Facebook connectedness was not significantly associated with neural activity in each region within the mentalizing network in the Cyberball task (Table x).

3.3 Habitual Facebook use and neural responses to social exclusion

We also investigated whether participants’ habitual Facebook use was linked to neural responses to social exclusion in the social pain and mentalizing networks in the Cyberball task. Our analyses indicated no significant association between habitual Facebook use and neural activity in the social pain network in the Cyberball exclusion vs. inclusion contrast (B = 0.02, 95% CI = [-0.12, 0.16], p = 0.79). Further, habitual Facebook use was not significantly associated with neural activity in each region (VS and LOFC) within the social pain network in the Cyberball task (Table x).

With regards to the mentalizing network, we observed a significant positive association between habitual Facebook use and neural activity in the mentalizing network in the Cyberball exclusion vs. inclusion contrast (B = 0.13, 95% CI = [0.002, 0.25], p = 0.046; Figure 3a). Further exploratory analyses that separately examined each region in the mentalizing network indicated that habitual FB use was significantly associated with neural activity in the DMPFC and bilateral TPJ (Table x; Figure 3b-d). These findings indicate that individuals who reported more habitual and automatic Facebook use also showed higher neural activity in the mentalizing network when being socially excluded in the Cyberball task.

3.4 Facebook measures and need threat after social exclusion

We conducted two OLS models to separately examine the link between Facebook measures (Facebook connectedness and habitual Facebook use) and participants’ self-report need threat after Cyberball social exclusion. We observed a marginal negative association between Facebook connectedness and need threat after social exclusion (beta = -0.29, 95% CI [-0.59, 0.02], p = 0.07), and a significant negative association between habitual Facebook use and need threat (beta = -0.20, 95% CI [-0.39, -0.02], p = 0.03). This result suggests habitual Facebook use significantly predicted less psychological distress after social exclusion, and that Facebook connectedness was marginally associated with less distress after social exclusion.

Figures

Figure 1. Word clouds of participants’ qualitative feedback on their Facebook use in relation to their reported (a) Facebook connectedness and (b) habitual use.

A close up of a piece of paper

Description automatically generated

Figure 2. Ordinary Least Square model results of linking Facebook connectedness and participants’ neural activity in the social pain ROIs (a: VS; b: LOFC) during social exclusion in Cyberball, controlling for age and sample wave.

A screenshot of a cell phone

Description automatically generated

Figure 3 Ordinary Least Square model results of linking habitual Facebook use and participants’ neural activity in the (a) mentalizing ROIs as well as the subregions (b: DMPFC; c: LTPJ; d: RTPJ) during social exclusion in Cyberball, controlling for age and sample wave.

A close up of a map

Description automatically generated

Tables

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

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| Habitual Facebook Use Scale (rated on a seven-point scale; [Bayer & Campbell, 2012; Verplanken & Orbell, 2003)](https://paperpile.com/c/2aJ6kC/65Apr+n23GM) |
| 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".   Facebook connectedness 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. |