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# Neural responses to exclusion predict susceptibility to social influence

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## Abstract

**Purpose—**Social influence is prominent across the lifespan, but sensitivity to influence is especially high during adolescence, and is often associated with increased risk taking. Such risk taking can have dire consequences. For example, in American teens, traffic-related crashes are leading causes of non-fatal injury and death. Neural measures may be especially useful in understanding the basic mechanisms of adolescents' vulnerability to peer influence.

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**Implications and contribution**: Adolescents who show the greatest neural reactivity to exclusion may be most susceptible to risk taking in the presence of peers. Neural responses provided information that was not evident from self-reports of susceptibility to peer pressure or participants' distress during exclusion, lending new insight into the mechanisms of peer influence and risk.

**Methods—**We examined neural responses to social exclusion as potential predictors of risk taking in the presence of peers in recently-licensed adolescent drivers. Risk taking was assessed in a driving simulator session occurring approximately one week after the neuroimaging session.

**Results—**Increased activity in neural systems associated with the distress of social exclusion and mentalizing during an exclusion episode predicted increased risk taking in the presence of a peer (controlling for solo risk behavior) during a driving simulator session outside of the neuroimaging lab one week later. These neural measures predicted risky driving behavior above and beyond self-reports of susceptibility to peer pressure and distress during exclusion.

**Conclusions—**These results speak to the neural bases of social influence and risk taking; contribute to our understanding of social and emotional function in the adolescent brain; and link neural activity in specific, hypothesized, regions to risk-relevant outcomes beyond the neuroimaging lab. Results of this investigation are discussed in terms of the mechanisms underlying risk taking in adolescents and the public health implications for adolescent driving.

### Keywords

adolescent behavior; risk taking; driving; social exclusion; social influence; peer influence; social pain; mentalizing; fMRI; neuroimaging

## INTRODUCTION

Adolescence is a period characterized by heightened responsivity to social influence across domains [1–4], including increased risk taking in the presence of peers [5–7]. This can have dire consequences. For example, in U.S. adolescents, traffic-related crashes are leading causes of non-fatal injury and death [8]. Evidence is strong that adolescents drive in a more risky fashion compared to adults [9]. Furthermore, adolescents drive in a more risky fashion in the presence of passengers [10], with fatal crashes rates being higher among adolescent drivers carrying young passengers [11, 12].

Neural measures may be especially useful in understanding the basic mechanisms of adolescents' vulnerability to peer influence and risk taking. For example, well-established theories suggest that the imbalance between relatively more rapid development of affective processing systems than cognitive control systems leaves adolescents more vulnerable to risk taking than other developmental groups [5, 6]. However, adolescents are not uniformly susceptible to risk [7, 13–15]; recent empirical work and reviews highlight the likely importance of social context and motivational salience [7, 14, 16, 17], among other factors [13], in affecting adolescent responses to social-cognitive and –affective cues, as well as resulting risk-taking behavior. However, current understanding of the neural mechanisms of peer influence on risk taking, as well as knowledge of how neural responses to social cues might interact with context and motivation in adolescents, are extremely limited (c.f., [18]).

One form of sensitivity to social cues is the cognitive ability to consider and make sense of the contents of other people's minds (termed mentalizing). Primary brain regions associated with mentalizing include the dorsomedial prefrontal cortex (DMPFC) [19], right temporal parietal junction (TPJ) [20, 21], and posterior cingulate cortex (PCC) [22, 23]. Individual

differences in the sensitivity of this system may also be associated with broader susceptibility to social influence.

A second form of sensitivity to social cues includes affective responses to being accepted or rejected by others [7]. Prior research has demonstrated that heightened reward activity in the presence of peers is associated with risk taking in adolescents [24]. Conversely, sensitivity to 'social pain' [25] has not been examined as a predictor of susceptibility to risky influence, and is the focus of the present investigation. Social pain is associated with increased neural activity in the anterior insula (AI) and subgenual anterior cingulate cortex (subACC) in adolescents [26], as well as in the dorsal anterior cingulate cortex (dACC) in adults [25, 27, 28]. Activity within this system is thought to signal that one may not be in line with the group, among other things, and is associated with restoring normative behavior [29, 30]. The social pain system may serve to promote learning that keeps individuals in harmony with the group [26, 31].

## Hypotheses

Consistent with theories that focus on social monitoring during exclusion as a means of remaining or being included as part of the group [32–34], to the extent that individuals are more sensitive to social cues and experience greater physiological reactivity to exclusion they might be more inclined to behave in ways that preemptively avoid exclusion and promote bonding during general social interactions [35]. Given that risk taking in adolescence can be a means of gaining social acceptance [36], those who are more responsive to acute social threats might preemptively adjust their behavior to fit in with group norms across situations. More specifically, we hypothesized that adolescents' increased activity in neural systems associated with social-cognitive sensitivity to social cues (mentalizing: DMPFC [19], right TPJ [20, 21], and PCC [22, 23]), as well as social-affective sensitivity to social cues ('social pain': AI, subACC [26]) during exclusion would be associated with differences in risk taking in the presence of peers in a separate simulated driving session, controlling for solo risk-taking behavior. It is also possible that the dACC might play a role, given prior findings regarding social pain in adults [25, 27, 28].

To test these hypotheses, we conducted a two-appointment study in which neural responses were recorded using fMRI during social exclusion in an especially at-risk group for fatal crash: recently licensed male adolescents [11, 37]. Individual differences in neural sensitivity to exclusion during the initial fMRI scan were then used to predict individual differences in risk taking in the presence of peers, controlling for solo risk behavior, in a separate driving simulator session approximately one week later (Figure 1). Driving simulation is consistently associated with a number of real-world driving behaviors [38], and is a safe method for investigating the effect of peer influences on risky-driving behavior, while maintaining both a high degree of experimental control and external validity [39].

## MATERIALS AND METHODS

### Participants

Thirty-six neurotypical adolescent males aged 16–17 years ($M$ = 16.8, $SD$ = .47) were recruited through the Michigan state driver registry database (Driver History Record) as part of a larger study on peer influences on adolescent driving [40]. These participants successfully completed both an fMRI session as well as a separate driving simulator appointment approximately one week later (Figure 1; see supplemental materials for full recruitment and simulator details). Within the 4–9 months prior to the scan, all participants had obtained a Level 2 (intermediate) Michigan driver license allowing them to drive independently, but with passenger and night driving restrictions. In addition, participants met standard MRI safety criteria (supplemental materials). Legal guardians provided written informed consent, and adolescents provided written assent.

### Procedure

**Session 1: fMRI—**At their first (fMRI) session, participants were introduced to two gender-matched peer confederates. Participants were told that they would be playing some computer games on their own, as well as in a group with the other "participants." Research assistants then took them to separate private rooms where the real participant completed the online pre-scan questionnaires and was given further instructions about the fMRI tasks; the confederates were not involved further in study procedures. Participants next completed a series of tasks within the fMRI scanner, including a game called Cyberball. Cyberball has been validated in a number of behavioral and neuroimaging studies as a reliable way of simulating the experience of social exclusion [27, 41]. A fair game of Cyberball was always played first, in which the participant and two virtual players received the ball equally often. This was followed by an unfair game, in which the participant and virtual players started out receiving the ball equally often, but where the participant was left out after a few throws, simulating exclusion. Order of the rounds was held constant to preserve the psychological experience across participants (detail in supplemental materials). Following the scan, participants completed a second set of questionnaires, including all of the questionnaires that are the focus of this investigation.

**Self-reports:** Participants completed online self-report assessments of susceptibility to peer pressure, SPP [42, 43], resistance to peer influence, RPI [44], and distress during the exclusion episode (the Need Threat Scale, NTS) [45] using Qualtrics. Higher SPP scores indicate increased susceptibility to peer pressure. Higher RPI scores indicate greater ability to resist peer influence. Higher NTS scores indicate greater need satisfaction and lower scores indicate greater threat or distress.

**Session 2: Driving simulation—**Approximately one week following the fMRI session, participants completed a driving simulator appointment. Within this session, participants drove a practice drive to habituate to a state-of-the-art fixed-base driving simulator (Figure 2; supplemental materials). All participants then drove alone and in the presence of a young, male confederate, whose behavior was manipulated to portray one of two risk levels (risk

accepting or not risk accepting) as part of a larger study on susceptibility to normative pressures in the driving context [40].[1]

Participants were randomly assigned to conditions blindly by an investigator who was not involved in any of the fMRI or simulator testing within a 2×2×2 counterbalanced block design comprised of conditions: confederate passenger behavior (high risk vs. low risk) X drive order (drove alone or with the confederate passenger first) X order of scenarios presented within each drive (order A or order B). The solo and passenger drives each consisted of the same number of intersections and yellow light scenarios.

## Data Acquisition and Analysis

**fMRI Data—**Imaging data were acquired using a 3 Tesla GE Signa MRI scanner. One functional run was recorded for each participant (251 volumes) during the Cyberball tasks. Functional data were prepared using a standard preprocessing stream and analyzed using Statistical Parametric Mapping [46]. Data were modeled using the general linear model as implemented in SPM8. Three trial phases were modeled: social inclusion, social exclusion, and the visual tracking phase. Additional details on scanning parameters, processing and modeling are available in the supplemental materials.

**Regions of Interest (ROIs)—**ROIs were constructed for each of the two a priori hypothesized networks of interest (social pain, Figure 3a; mentalizing, Figure 5a; ROI definitions in supplemental materials). The social pain network was defined based on prior work examining the discomfort of exclusion in adolescents [26] to include bilateral AI and subACC (Figure 3a). An additional, exploratory, network was constructed to also include the dACC, given prior findings regarding social pain in adults [25, 27, 28]. The mentalizing network was defined to include DMPFC, right TPJ, and PCC (Figure 5a) [19–23]. Separate ROIs for subregions within each network were also constructed in order to facilitate secondary follow-up analyses parsing which regions within the network drive the effects observed. Finally, we identified regions within the broader anatomically defined ROIs that were associated with the main effect of exclusion > inclusion during Cyberball (Figures 4a, 6a; Table S5), treated as functionally defined regions of interest (fROIs). The anatomical ROI estimates reflect individual differences in neural activity within a priori hypothesized regions. Supplemental analyses focusing on the fROIs a) confirm that the task is engaging the regions expected, and b) provide a way of testing whether the sub-regions that are engaged during exclusion most (on average) predict changes in our dependent measures of risk taking.

## Analysis plan

Neural data and driving simulator data were combined using a brain-as-predictor framework [47] in a series of ordinary least squares regressions, implemented in R version 2.15.1. Predictors of interest were estimates of exclusion-related neural activity in the social pain network and the mentalizing network. Parameter estimates from the anatomical and

[1]This manipulation and associated effects from the larger study are described in more extensive detail elsewhere (Simons-Morton et. al., in press) and are not the focus of the current investigation. However, confederate behavior is accounted for in all of our models.

functional ROIs where extracted for each subject using MarsBar from the exclusion > inclusion contrast. Estimates from the functional ROIs were extracted at the cluster level. All extracted parameter estimates were transformed into units of percent signal change by dividing by the grand mean value from the whole run of Cyberball [48, 49] and then used as predictors of risky behavior in subsequent models.

Our primary dependent measure of risk taking was the proportion of time during each drive that participants were in the intersection when the traffic signals were red (percent red). The simulation was designed to present dilemma zone (yellow light) situations that would elicit risk-taking behaviors, i.e. willingness to run the light. Time spent in the intersection while the light is red is indicative of the driver's willingness to push through lights in a dilemma situation, a measure that is translatable to real-world driving where intersection crashes can be among the most serious [40].

We operationalized susceptibility to social influence in terms of risk-taking behaviors during the passenger drive, controlling for baseline (solo) risk-taking behavior. We ran separate, successive regression models to examine the relationships between neural activity in our a priori hypothesized mentalizing and social pain networks, respectively, and risk taking during the passenger drive. Parallel models were then run examining self-reports of distress during exclusion and susceptibility to peer pressure as predictors, respectively. Finally, neural data and self-report data were entered in a series of combined models that examined the effects of each neural network, separately, above and beyond self-report predictors. To control for potential learning effects of repeated exposure to the driving simulator, as well as confederate behavior, all models also included solo drive risk-taking behavior, confederate condition (risk accepting vs. not risk accepting), and drive order (participant first vs. confederate first) as covariates.

## RESULTS

### Behavioral results

**Self-reports—**At baseline, participants reported being somewhat unsusceptible to peer influence (SPP: $M = 1.95$, corresponding to an average response indicating that they would "probably not" go along with their friend's risky behavior, $SD = .49$, Cronbach's alpha = .78), and somewhat more similar to the person who resists peer influence than to someone who is susceptible to peer influence (RPI: $M = 2.93$, $SD = .46$, Cronbach's alpha = .53). Given that RPI did not exhibit strong reliability and the results of our primary target analyses are similar for both SPP and RPI, we report results throughout the rest of the paper focusing on SPP. Consistent with past work examining the effects of cyberball in adolescents [26], participants reported relatively neutral levels of threat following exclusion (NTS overall score: $M = 3.89$, corresponding to an average response between "neither agree nor disagree" to "somewhat disagree", with respect to items measuring felt threat, $SD = .97$, Cronbach's alpha = .92).

**Risky behavior during the drives—**Risk taking during solo and passenger driving were highly correlated with one another ($r=.78$, $p<.001$). Consistent with prior findings [24], however, we observed a main effect of passenger presence, such that on average,

participants drove in a riskier manner during the passenger drive (percent red: *M* =.21; *SD* = .17) than during the solo drive (percent red: *M* = .13; *SD* =.14), $t(36) = 4.33$, $p < .001$; higher percentages of time in the intersection when the light is red indicates increased risk taking). We also observed an effect of confederate passenger type, such that participants exposed to the risk-accepting confederate passenger took more risks on average than those exposed to the risk-averse confederate passenger ($t(34) = -2.15$, $p=0.04$), though participants took more risks with both types of passengers compared to driving alone ($t(35) = 4.29$, $p < 0.001$). Confederate type did not interact with our neural predictors to predict risk taking or susceptibility to influence in any of the models that form the primary focus of this manuscript (p's range from .15 to .82).

**Self-report predictors of risky influence—**Self-reports of susceptibility to peer pressure were significantly positively associated with increased risk-taking behavior during the passenger drive (β =.23, $t(32) = 2.12$, $p = .042$), controlling for solo risk-taking behavior, confederate condition, and drive order. Self-reports of distress during exclusion were uncorrelated with risk-taking behavior during the passenger drive (β = .05, $t(32) = .48$, $p = .638$).

## Neural results

Neural activity in the social pain network previously observed in adolescents for the exclusion > inclusion contrast (AI + subACC) was significantly, positively associated with risky behavior in the driving simulator (Table 1a, Figure 3b); those who showed greater activity in the social pain network during exclusion > inclusion drove in a riskier manner in the presence of a peer, controlling for solo drive behavior. Parallel results were observed treating the change score from solo to passenger drive as the dependent measure. In addition, measures of neural activity in the social pain network remained significantly, positively associated with risk taking during the passenger drive, controlling for susceptibility to peer pressure (Table 1b) and controlling for distress during the exclusion episode (Table 1c). Parallel results were observed in our fROIs (Table 1d–f), and in the extended social pain network that included AI, subACC and dACC [25, 27, 28]. However, the results were strongest in the AI and subACC, regions that were also most strongly associated with the main effect of the task (Table S1; See also, supplemental whole brain search for regions associated with risk taking in passenger, compared to solo drives: Table S6).

We next examined activity in the mentalizing network during exclusion vs. inclusion as a predictor of later susceptibility to risky influence in the driving simulator (Table 2a). Consistent with the idea that broader sensitivity to social cues is associated with susceptibility to influence, neural activity in the mentalizing network (DMPFC + right TPJ + PCC; Figure 5a) was associated with risk taking during the passenger drive (Table 2a, Figure 5b). Parallel results were observed treating the change score from solo to passenger drive as the dependent measure. In addition, neural activity in the mentalizing network remained significantly positively associated with risk taking during the passenger drive, controlling for susceptibility to peer pressure and distress during the exclusion episode

(Table 2b–c; see Supplementary Table S2 for sub-region analyses), and using fROIs (Table 2d–f).

## 4. DISCUSSION

We examined neural and self-report predictors of susceptibility to risky social influence in a sample of recently-licensed adolescent drivers. Consistent with past work [24], the mere presence of a peer was enough to promote risk, whether or not explicit risky norms were communicated (though the effect was strongest with passengers that promote risk-accepting norms; [40]). Furthermore, increased activity in both social-cognitive (mentalizing) and social-affective (social pain) systems during exclusion predicted increased risky behavior in the presence of a peer (confederate), controlling for solo risk-taking behavior and the confederate's behavior. The brain undergoes development of both affective and social cognitive systems across adolescence [5, 15, 16, 50–53], and adolescence is thought to be a period of reorienting "social and motivational tendencies, which in turn influence behavior and emotion in adolescence depending upon interactions with social context" [54]. Our data suggest that individual differences in the responsiveness of these systems may relate to adolescent behavior in the presence of peers, controlling for their solo risk behavior.

Social psychologists have suggested that one function of human susceptibility to social influence is to promote bonding and group harmony [55], and humans have developed strong biological alarm systems to prevent social isolation [25, 27, 56–60]. Indeed, social monitoring during exclusion may serve as a means of remaining connected with the group [32–34]. More generally, these results may be interpreted within the framework of rewards and punishments that are known to drive human and animal behavior and learning [56, 61–65]. Both real and anticipated rewards reinforce behaviors, whereas real and anticipated punishments inhibit behaviors that are known to produce punishment [66–70], with variation in individual differences regarding sensitivity to rewards and punishments in motivating behavior [61–63]. Our data suggest such differences may also translate into susceptibility to behavior change in the presence of peers and indicate specific neural processes that may underlie such effects; adolescents whose brains are more responsive to social cues during exclusion may be more likely to change their behavior in the presence of peers (perhaps to avoid social exclusion or promote affiliation), regardless of whether peers explicitly encourage risk or not.

### Neural activity explains variance in risky behavior that is not explained by self-reports

Activity in both the social pain and mentalizing networks remained significant predictors of risky driving in the presence of a peer, not only when controlling for individual differences in solo risk behavior and confederate behavior, but also when controlling for self-reports of susceptibility to peer pressure [42] and distress during Cyberball. Although self-reported susceptibility to peer pressure predicted risk taking in the presence of a passenger during the driving simulator session, when neural activity and self-report were simultaneously modeled, the neural activity predicted variance in the behavioral outcome, above and beyond self-report. This suggests that the neural measure of 'social pain' may index processes and capture information that participants either are not consciously aware of, or

are unwilling to report (e.g., due to self-presentation concerns that are especially salient during adolescence).

### Strengths and limitations

The combination of highly controlled neuroimaging paradigms with outcome data from a social interaction in a driving simulator allowed us a high degree of control over external confounds, while still maintaining a high degree of internal and external validity. However, limitations present opportunities for future research. First, though recruited broadly from our target population via the Driver History Record, the final sample is not a random subset of the population given that participants were all volunteer responders. Second, our chief findings are correlational; it is possible that individuals who later took more risks in the presence of peers also showed increased responsiveness in the social pain and mentalizing networks due to a third variable, or that susceptibility to risky peer influence sensitizes the brain systems in question. Prior work [26] reported that neural activity in the brain's social pain network (including dACC, subgenual ACC, and anterior insula), as well as DMPFC during exclusion > inclusion were associated with interpersonal competence scores in adolescents, which may also be associated with social influences [71]. Third, driving simulators provide external validity with respect to relative risk behavior under different conditions, while controlling for a number of confounding variables in actual driving, and ethically manipulating crash risk [38, 39]. However, future research that combines parallel neural measures with instrumented vehicles on real roads would provide additional information about the relationship between our neural variables and naturalistic driving. Finally, we focused on recently licensed male adolescents, given that they are the highest risk group for fatal crash, especially in the presence of other male adolescents [11, 37]. Future research on samples that include both men and women, as well as younger and older participants, and other risk behaviors will inform the boundary conditions on the effects observed. It is also possible that more robust effects of susceptibility to peer pressure would be observed if peer pressure were more directly applied, suggesting a key avenue for future research.

## CONCLUSION

Adolescents who demonstrated greatest activity in social-cognitive (mentalizing) and social-affective (social pain) brain systems during exclusion showed greatest susceptiblity to risk taking in the presence of peers, suggesting potential mechanisms of peer influence on risk taking in adolescents. Furthermore, neural activity forecasted variability in driving risk with a peer that was not explained by self-report alone. Given that traffic-related crashes are a leading cause of adolescent mortality and non-fatal injury, these data also contribute understanding that might eventually inform programs and policies to reduce injury and fatalities in adolescents.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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**Figure 1. Overview of study protocol**

First, participants completed an fMRI scanning session in which neural activity was recorded during an exclusion episode. Next, approximately one week later, driving behavior was recorded in a driving simulator, while participants drove alone, and in the presence of a peer (confederate).

**Figure 2. Driving Simulator**

During the driving session, participants drove in a fixed-base, partial cab driving simulator.

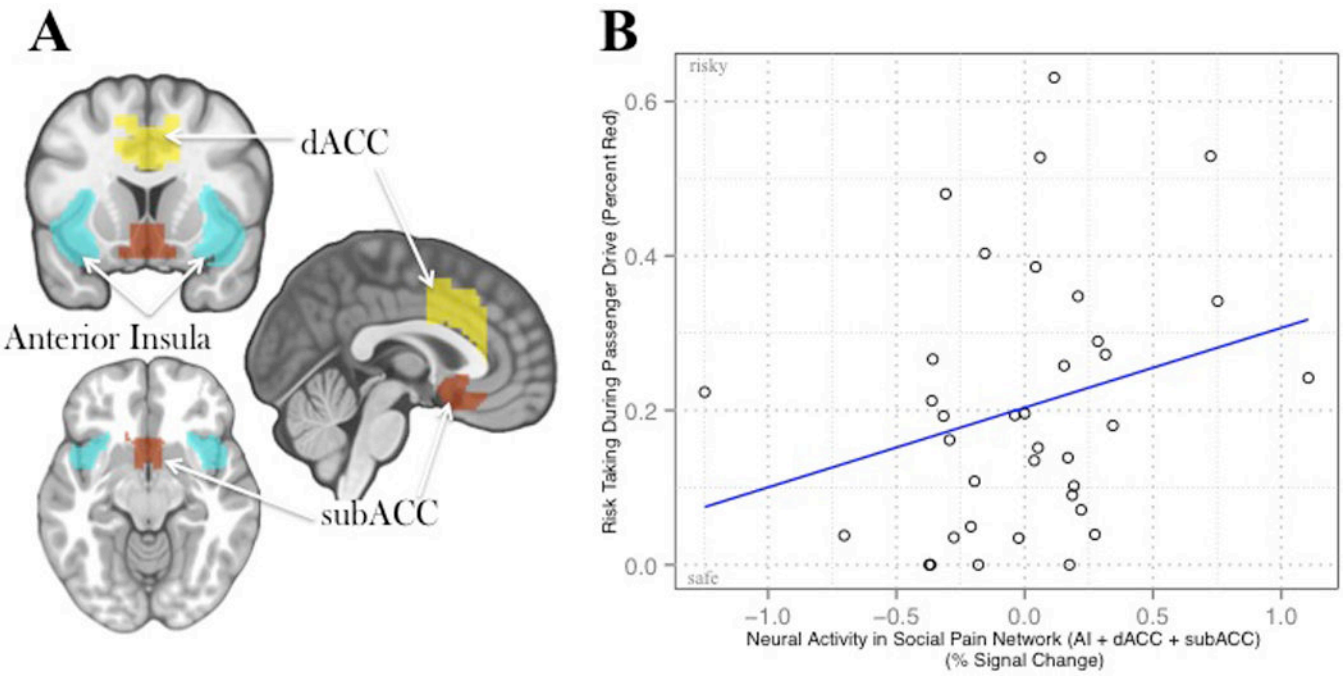


**Figure 3.**

3a. Anatomical regions of Interest (ROIs) comprising the putative social pain system. Primary results averaged activity in anterior insula (AI) and subgenual anterior cingulate cortex (subACC). Additional results also computed including the dorsal anterior cingulate cortex (dACC). 3b) Scatter plot of residualized parameter estimates (percent signal change for exclusion > inclusion) extracted from the combined ROIs during Cyberball predicting risk taking during the passenger drive, controlling for drive order, passenger type and solo drive behavior.

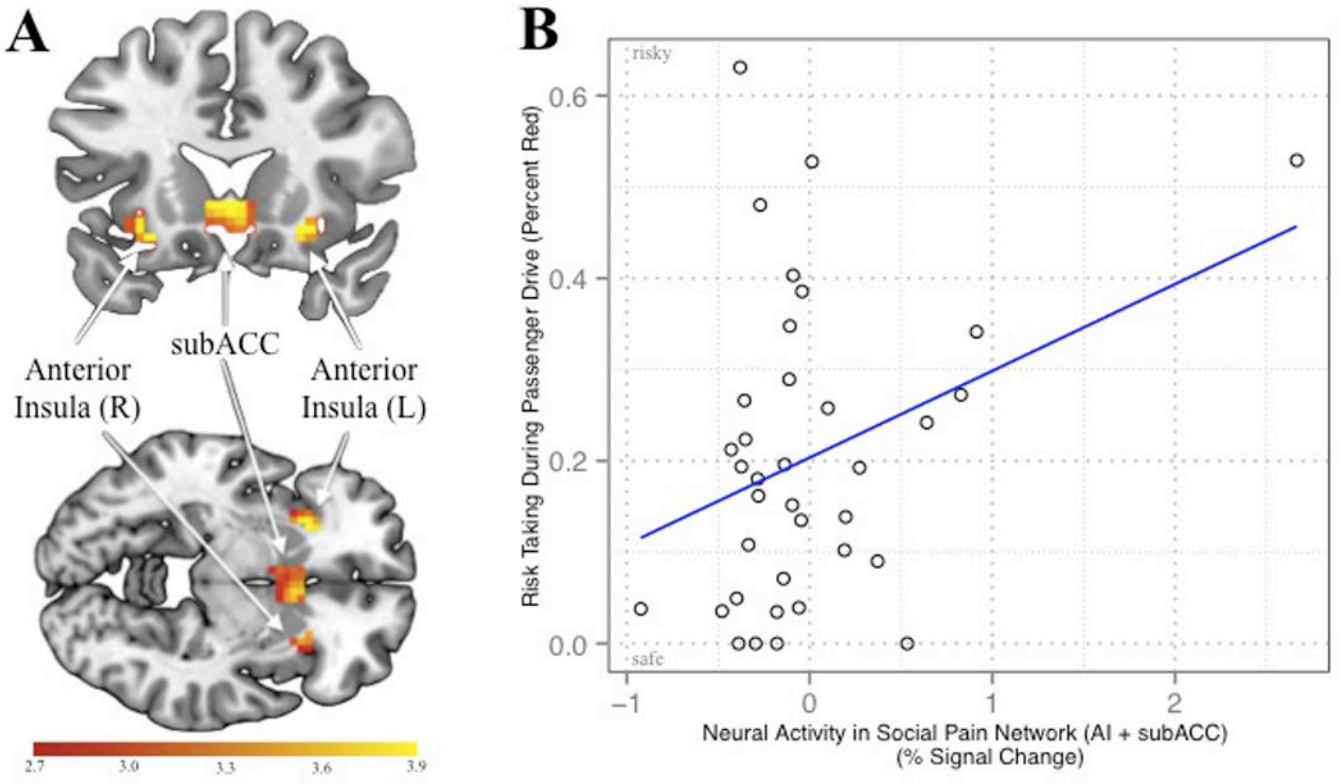


**Figure 4.**

4a. Functional regions of interest (fROIs) were identified within the anatomical ROIs pictured in Figure 3, during exclusion compared to inclusion (thresholded at p<.005, k=10). 4b) Scatter plot of residualized parameter estimates (percent signal change for exclusion > inclusion) during Cyberball within the identified clusters, predicting risk taking during the passenger drive, controlling for drive order, passenger type and solo drive behavior.

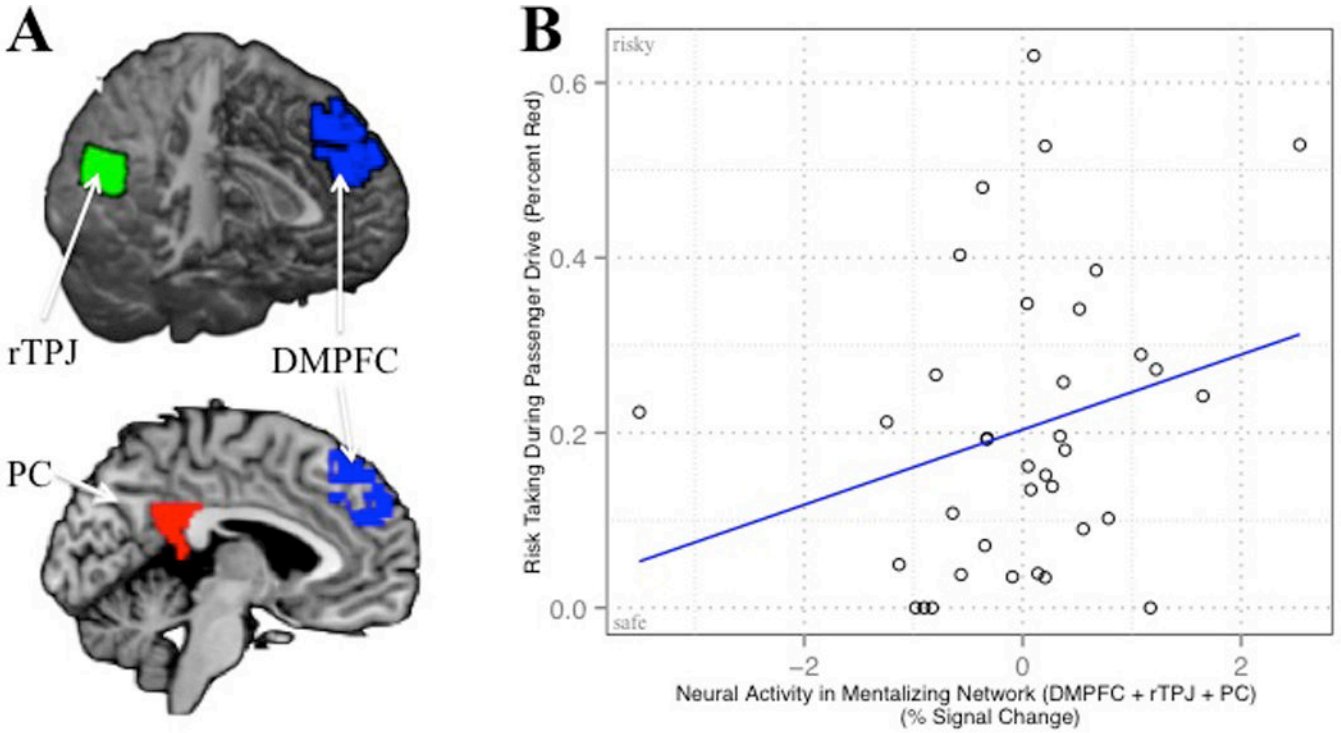


**Figure 5.**

5a. Anatomical regions of Interest (ROIs) comprising the mentalizing system. Primary results averaged activity in dorsal medial prefrontal cortex (DMPFC), right temporal parietal junction (right TPJ), and posterior cingulate cortex (PCC). 5b) Scatter plot of residualized parameter estimates (percent signal change for exclusion > inclusion) extracted from the combined ROIs during Cyberball predicting risk taking during the passenger drive, controlling for drive order, passenger type and solo drive behavior.

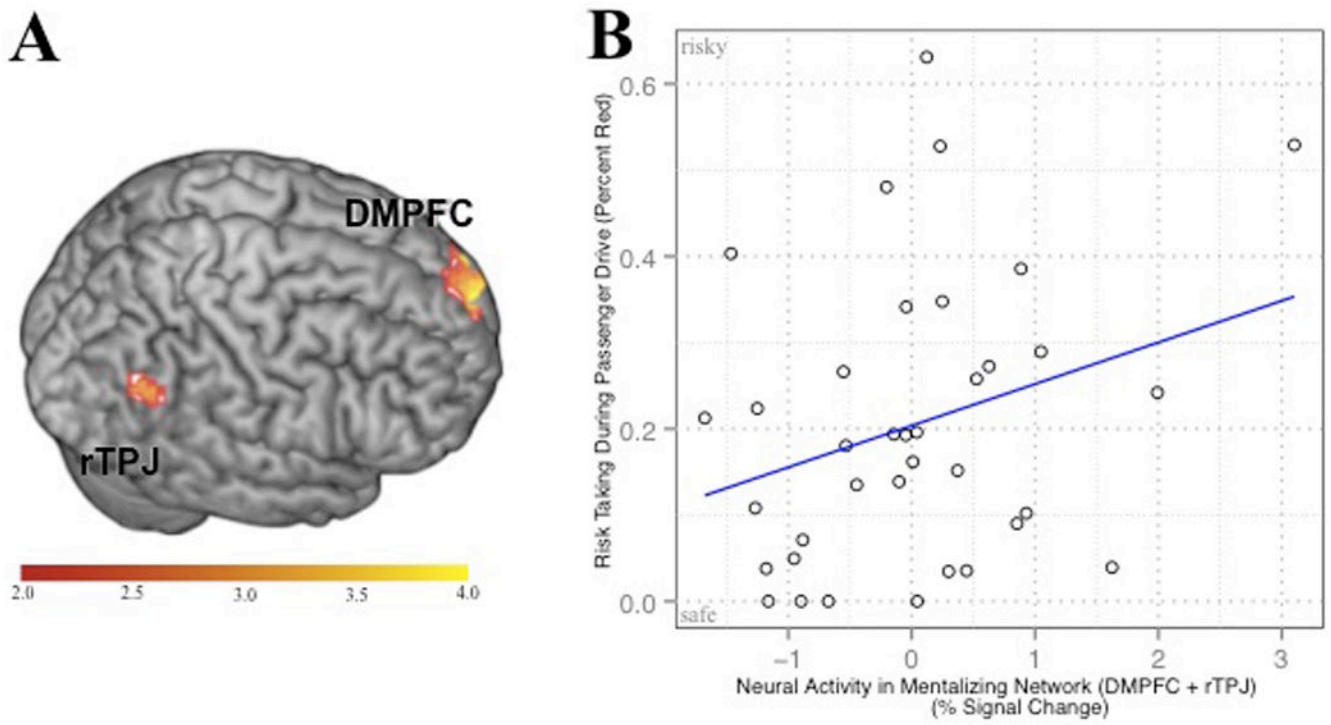


**Figure 6.**

6a. Functional regions of interest (fROIs) were identified within the anatomical ROIs pictured in Figure 5, during exclusion compared to inclusion (thresholded at p<.005, k=10). 6b) Scatter plot of residualized parameter estimates (percent signal change for exclusion > inclusion) during Cyberball within the identified clusters, predicting risk taking during the passenger drive, controlling for drive order, passenger type and solo drive behavior.

## Table 1

**Relationship between neural activity in the social pain network during Cyberball exclusion > inclusion and risk taking (percent red) in the presence of peers in the driving simulator session**

1a) Effect of neural activity in the social pain network (anterior insula (AI) and subgenual cingulate (subACC)), controlling for passenger type, drive order, and solo risk-taking behavior (as measured by performance in the solo drive at the simulator); 1b) Examines the same relationships as Model 1a, but controls for self-reported susceptibility to peer pressure (SPP); 1c) Examines the same relationships as Model 1a, but controls for distress during the exclusion episode (Cyberball), as measured by the need threat scale (NTS); 1d) Examines the same relationships as Model 1a, but replaces the anatomical ROI with a functional ROI defined based on exclusion > inclusion within hypothesized anatomical regions; 1e) Examines the same relationships as Model 1d, but controls for self-reported susceptibility to peer pressure (SPP); 1f) Examines the same relationships as Model 1d, but controls for distress during the exclusion episode (Cyberball), as measured by the need threat scale (NTS).

**a.**

| | **Unstandardized Coefficients** | | **Standardized Coefficients** | | |
|---|---|---|---|---|---|
| **Variable** | **B** | **Std. Error** | **Beta** | **t** | **Sig.** |
| Drive Order | 0.028 | 0.035 | 0.085 | 0.796 | 0.432 |
| Passenger Type | 0.091 | 0.036 | 0.276 | 2.546 | 0.016 |
| Solo Drive | 0.779 | 0.128 | 0.671 | 6.07 | < .001 |
| Cyber (AI & subACC) | 0.119 | 0.038 | 0.314 | 3.102 | 0.004 |
| | | | *N* = 36 | *Model R Square* = .718 | |

**b.**

| | **Unstandardized Coefficients** | | **Standardized Coefficients** | | |
|---|---|---|---|---|---|
| **Variable** | **B** | **Std. Error** | **Beta** | **t** | **Sig.** |
| Drive Order | 0.044 | 0.036 | 0.135 | 1.225 | 0.23 |
| Passenger Type | 0.081 | 0.036 | 0.246 | 2.269 | 0.031 |
| Solo Drive | 0.78 | 0.126 | 0.672 | 6.19 | < .001 |
| Cyber (AI & subACC) | 0.104 | 0.039 | 0.275 | 2.678 | 0.012 |
| SPP | 0.05 | 0.034 | 0.153 | 1.467 | 0.153 |
| | | | *N* = 36 | *Model R Square* = .737 | |

**c**

| | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|
| **Variable** | **B** | **Std. Error** | **Beta** | **t** | **Sig.** |
| Drive Order | 0.033 | 0.037 | 0.099 | 0.894 | 0.379 |
| Passenger Type | 0.096 | 0.037 | 0.289 | 2.567 | 0.016 |
| Solo Drive | 0.781 | 0.132 | 0.67 | 5.93 | < .001 |
| Cyber (AI & subACC) | 0.118 | 0.039 | 0.312 | 2.992 | 0.006 |
| NTS | 0.007 | 0.016 | 0.04 | 0.399 | 0.693 |
| | | | *N* = 36 | *Model R Square* = .721 | |

**d.**

| | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|
| **Variable** | **B** | **Std. Error** | **Beta** | **t** | **Sig.** |
| Drive Order | 0.034 | 0.033 | 0.105 | 1.029 | 0.311 |
| Passenger Type | 0.082 | 0.033 | 0.251 | 2.516 | 0.017 |
| Solo Drive | 0.739 | 0.123 | 0.637 | 5.997 | < .001 |
| Cyber fROI (AI & subACC) | 0.095 | 0.025 | 0.351 | 3.74 | 0.001 |
| | | | *N* = 36 | *Model R Square* = .746 | |

**e.**

| | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|
| **Variable** | **B** | **Std. Error** | **Beta** | **t** | **Sig.** |
| Drive Order | 0.05 | 0.034 | 0.151 | 1.442 | 0.16 |
| Passenger Type | 0.075 | 0.033 | 0.227 | 2.291 | 0.029 |
| Solo Drive | 0.743 | 0.121 | 0.64 | 6.141 | < .001 |
| Cyber fROI (AI & subACC) | 0.086 | 0.026 | 0.317 | 3.348 | 0.002 |
| SPP | 0.048 | 0.032 | 0.145 | 1.477 | 0.15 |
| | | | *N* = 36 | *Model R Square* = .763 | |

**f**

| | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|
| **Variable** | **B** | **Std. Error** | **Beta** | **t** | **Sig.** |
| Drive Order | 0.039 | 0.035 | 0.118 | 1.116 | 0.273 |
| Passenger Type | 0.088 | 0.035 | 0.264 | 2.536 | 0.017 |



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**f**

| | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|
| **Variable** | **B** | **Std. Error** | **Beta** | **t** | **Sig.** |
| Solo Drive | 0.741 | 0.127 | 0.635 | 5.854 | < .001 |
| Cyber fROI (AI & subACC) | 0.095 | 0.026 | 0.35 | 3.614 | 0.001 |
| NTS | 0.004 | 0.016 | 0.027 | 0.28 | 0.782 |
| | | | *N* = 36 | *Model R Square* = 0.748 | |

**Table 2**

**Relationship between neural activity in the mentalizing network during Cyberball and risk taking (percent red) in the presence of peers in the driving simulator session**

2a) Effect of neural activity in the mentalizing network (dorsal medial prefrontal cortex (DMPFC), right temporal parietal junction (rTPJ), and posterior cingulate cortex (PCC)), controlling for passenger type, drive order, and solo risk-taking behavior (as measured by performance in the solo drive at the simulator); 2b) Examines the same relationships as in Model 2a, but controls for self-reported susceptibility to peer pressure (SPP); 2c) Examines the same relationships as Model 2a, but controls for distress during the exclusion episode (Cyberball), as measured by the need threat scale (NTS); 2d) Examines the same relationships as Model 2a, but replaces the anatomical ROI with a functional ROI defined based on exclusion > inclusion within hypothesized anatomical regions; 2e) Examines the same relationships as Model 2d, but controls for self-reported susceptibility to peer pressure (SPP); 2f) Examines the same relationships as Model 2d, but controls for distress during the exclusion episode (Cyberball), as measured by the need threat scale (NTS).

**a.**

| | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|
| **Variable** | **B** | **Std. Error** | **Beta** | **t** | **Sig.** |
| Drive Order | 0.005 | 0.037 | 0.017 | 0.148 | 0.884 |
| Passenger Type | 0.075 | 0.036 | 0.229 | 2.11 | 0.043 |
| Solo Drive | 0.822 | 0.132 | 0.708 | 6.229 | < .001 |
| Cyber (DMPFC, rTPJ, & PCC) | 0.079 | 0.03 | 0.274 | 2.629 | 0.013 |
| | | | *N* = 36 | *Model R Square* = .698 | |

**b.**

| | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|
| **Variable** | **B** | **Std. Error** | **Beta** | **t** | **Sig.** |
| Drive Order | 0.027 | 0.038 | 0.082 | 0.706 | 0.486 |
| Passenger Type | 0.066 | 0.035 | 0.202 | 1.888 | 0.069 |
| Solo Drive | 0.817 | 0.129 | 0.704 | 6.354 | < .001 |
| Cyber (DMPFC, rTPJ & PCC) | 0.069 | 0.03 | 0.237 | 2.287 | 0.029 |
| SPP | 0.057 | 0.035 | 0.172 | 1.628 | 0.114 |
| | | | *N* = 36 | *Model R Square* = .723 | |

**c.**

| | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|
| **Variable** | **B** | **Std. Error** | **Beta** | **t** | **Sig.** |
| Drive Order | 0.011 | 0.038 | 0.034 | 0.292 | 0.773 |
| Passenger Type | 0.082 | 0.038 | 0.248 | 2.191 | 0.037 |
| Solo Drive | 0.825 | 0.135 | 0.708 | 6.106 | < .001 |
| Cyber (DMPFC, rTPJ & PCC) | 0.079 | 0.031 | 0.274 | 2.572 | 0.015 |
| NTS | 0.01 | 0.017 | 0.063 | 0.607 | 0.549 |
| | | | *N* = 36 | *Model R Square* = .703 | |

**d.**

| | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|
| **Variable** | **B** | **Std. Error** | **Beta** | **t** | **Sig.** |
| Drive Order | −0.007 | 0.036 | −0.02 | −0.185 | 0.854 |
| Passenger Type | 0.068 | 0.034 | 0.208 | 2.025 | 0.052 |
| Solo Drive | 0.828 | 0.127 | 0.714 | 6.507 | < .001 |
| Cyber fROI (DMPFC & rTPJ) | 0.072 | 0.023 | 0.314 | 3.124 | 0.004 |
| | | | *N* = 36 | *Model R Square* = .719 | |

**e.**

| | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|
| **Variable** | **B** | **Std. Error** | **Beta** | **t** | **Sig.** |
| Drive Order | 0.01 | 0.04 | 0.031 | 0.26 | 0.797 |
| Passenger Type | 0.062 | 0.034 | 0.19 | 1.818 | 0.079 |
| Solo Drive | 0.824 | 0.127 | 0.71 | 6.479 | < .001 |
| Cyber fROI (DMPFC & rTPJ) | 0.062 | 0.025 | 0.269 | 2.456 | 0.02 |
| SPP | 0.038 | 0.037 | 0.115 | 1.03 | 0.311 |
| | | | *N* = 36 | *Model R Square* = .729 | |

**f.**

| | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|
| **Variable** | **B** | **Std. Error** | **Beta** | **t** | **Sig.** |
| Drive Order | 0.001 | 0.037 | 0.002 | 0.014 | 0.989 |
| Passenger Type | 0.079 | 0.035 | 0.239 | 2.242 | 0.033 |

**f.**

| | Unstandardized Coefficients | | Standardized Coefficients | | |
|---|---|---|---|---|---|
| **Variable** | **B** | **Std. Error** | **Beta** | **t** | **Sig.** |
| Solo Drive | 0.832 | 0.129 | 0.714 | 6.469 | < .001 |
| Cyber fROI (DMPFC & rTPJ) | 0.075 | 0.023 | 0.327 | 3.204 | 0.003 |
| NTS | 0.014 | 0.016 | 0.085 | 0.853 | 0.401 |
| | | | *N* = 36 | *Model R Square* = .730 | |