Cultural context moderates neural pathways to social influence

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Abstract

People from different cultural backgrounds respond differently to social cues, and may use their brains differently in social situations. Socioeconomic status (SES) is one key cultural variable that influences susceptibility to social cues, with those from lower SES backgrounds tending toward greater interdependence, and those from higher SES backgrounds tending toward greater independence. Building on past research linking brain sensitivity during social exclusion with tendency to take risks in the presence of peers, we examined whether SES moderated the relationship between neural measures of sensitivity during social exclusion and later conformity to peer pressure in a driving simulator. Our data show that SES does moderate the relationship between brain responses during social exclusion and conformity to peer influence on driving behavior. Specifically, increased activity in brain regions implicated in social pain and reward-sensitivity during social exclusion were associated with greater conformity to peer passenger driving norms for low SES and decreased conformity for high SES. In addition, increased activity brain regions implicated in understanding others' mental states during exclusion was associated with similar patterns of decreased conformity for high SES. Overall, results highlight the importance of considering cultural factors, such as SES, in understanding the relationship between neural processing of social cues and how these translate into real-world relevant behaviors.

Keywords: socioeconomic status, social exclusion, social influence, adolescence, fMRI

Introduction

Cultural neuroscience is a growing interdisciplinary field that seeks to understand how socio-cultural level factors influence psychological and neural processing (Kitayama & Park, 2010). Research in this field has demonstrated that psychological processes can be influenced by socio-cultural environments through expressed explicit values, shared cultural behaviors, and implicit psychological or neural processes (Kitayama & Park, 2010). Although many of the existing papers in cultural neuroscience have focused on country level differences in socio-cultural environments, local socio-cultural environments, such as one's socioeconomic status (SES), have also been shown to influence psychological and neural processing (Hackman & Farah, 2009), and SES has been conceptualized as an important cultural variable (Cohen, 2009).

In line with a view of SES as an important socio-cultural variable, people from different SES backgrounds are differentially sensitive to social cues (for reviews, see (Hong & Chiu, 2001; Kraus, Piff, Mendoza-Denton, Rheinschmidt, & Keltner, 2012)), and the meaning of brain activity may differ depending on cultural background (Kitayama & Park, 2010; Tompson, Lieberman, & Falk, 2015). For example, research examining biological and psychological responses to ambiguous events found that participants from lower SES backgrounds showed greater heart rate activity and increased blood pressure, as well as interpreting events as more threatening compared to participants from higher SES backgrounds (Chen, Langer, Raphaelson, & Matthews, 2004). In addition, individuals from higher SES backgrounds tend to have an internal and individualistic orientation, whereas those from lower SES backgrounds tend to have an external and interdependent orientation (Kraus et al., 2012). In turn, differences in sensitivity to, and responses to, social cues may have consequences for a wide range of important outcomes, such as behavioral responses to social influence from peers.

Behavioral responses to social influence are particularly strong and important during adolescence. Adolescents tend to exhibit heightened sensitivity to social rewards and punishments (Somerville, Jones, & Casey, 2010), as well as increased risk taking (Chein, Albert, O'Brien, Uckert, & Steinberg, 2011; Steinberg, 2008), though the extent of these tendencies vary substantially across individuals. This has consequences for a range of important outcomes. For example, people who are more sensitive to social rewards and threats during every day social interactions may take action in order to maintain positive social status and avoid exclusion in the future (for a review, see (Falk, Way, & Jasinska, 2012)). Conformity to social norms is one possible way to achieve positive social status in some groups; assertion of dominance or resisting social norms may be a way to achieve positive social status in other groups. No prior work, however, has examined the link between sensitivity to social rewards and punishments and later conformity in relation to SES. Specifically, sensitivity to social rewards, social threats, and general sensitivity to social cues may be differentially associated with susceptibility to social influence depending on cultural background. In line with this view, cultural background moderates the relationship between brain activity during cognitive tasks and behaviors such as risk taking (Telzer, Fuligni, & Gálvan, 2015) and prosociality (Telzer, 2016). Combined with greater tendencies toward interdependence, those from lower SES backgrounds who show greater neural sensitivity to social cues in exclusion may show greater tendencies to conform to peer influence; by contrast, those with greater tendencies toward independence who show greater neural sensitivity to social cues in exclusion may show greater tendency to assert this independence in their behavior.

Sensitivity to social exclusion and peer influence.

In line with this argument, in one study, neural responses to social exclusion within brain regions associated with conflict detection and distress (referred to as 'social pain' throughout the remainder manuscript) and inferring the mental states of others (referred to as mentalizing throughout the remainder manuscript) were associated with future differences in susceptibility to peer influence (Falk et al., 2014). More specifically, increased activity in the dorsal anterior cingulate cortex (dACC), anterior insula (AI), and subgenual cingulate (subACC), regions previously associated with social pain (Eisenberger, 2012; Eisenberger et al., 2003; Kross et al., 2011; Masten et al., 2009), during social exclusion, predicted increased risk taking in the presence of a peer one week later (Falk et al., 2014). In addition, increased activity in the right temporoparietal junction (rTPJ) and dorsomedial prefrontal cortex (DMPFC), regions associated with mentalizing (Saxe, 2010; Saxe & Wexler, 2005; Lieberman, 2010), during social exclusion, was associated with increased risk taking in the presence of a peer one week later (Falk et al., 2014). The authors argue that for those who are most sensitive and reactive to exclusion, it is adaptive to take steps to fit in (such as taking risks in adolescence); however, this research assumed that risk taking might help teens achieve positive social status, rather than separately examining the strength of the relationship between specific peer norms and driving behavior. Other research converges with the idea that during social influence increased activity in social pain regions may work as an internal signal that one is misaligned with others (e.g., peers), and activity in these regions is associated with conforming to the normative group behavior (Berns et al., 2010; Klucharev et al., 2009). In addition, mentalizing can also provide information that helps individuals to realign with group norms (Falk et al., 2014).

Finally, sensitivity to potential rewards (referred to in the current manuscript as 'reward sensitivity') in social situations is another pathway thought to promote conformity (Cascio, Scholz, & Falk, 2015). Teens show particularly heightened reward sensitivity in ventral striatum (VS) and ventromedial prefrontal cortex (VMPFC) in the presence of peers, relative to adults (Chein et al., 2011). Although reward sensitivity during social interactions can result in risky behavior (Chein et al., 2011), it can also lead to prosocial behaviors if social norms favor such behavior (Telzer, 2016). Thus, sensitivity within the reward system that is focused on becoming included, maintaining positive social status, or regulating feelings of distress during exclusion may lead some to take behavioral steps (e.g., conforming or asserting independence) to maintain positive social status. In line with this idea, reward pathways in the VMPFC (Ochsner & Gross, 2005; Quirk & Beer, 2006) and VS (Pfeifer & Allen, 2012; Telzer, 2016) have been implicated in regulation of emotion, and regulating negative affect in response to social exclusion, specifically (Eisenberger, Lieberman, & Williams, 2003).

Thus, differences in sensitivity to social cues may be tied to social pain, mentalizing, and reward sensitivity systems during exclusion; this sensitivity, in turn, may have behavioral consequences for how a person responds to situations that could affect social ties (e.g., conforming or independence-asserting responses to peer influence). All of these systems, and the meaning of their activation in relation to decision making, may be shaped and influenced by socio-cultural environmental factors, such as SES, but this has not been explored. Previous work examining a subset of the data reported in the current manuscript (the first cohort of fMRI participants) reported on the relationship between neural mechanisms associated with social exclusion and risk taking in the presence of a peer (Falk et al., 2014). Separately, other data reported in the current manuscript (the second cohort of the driving simulator participants) showed that peer norms can increase and decrease risk taking during simulated driving; i.e. teens conform to peer norms on driving in some circumstances (Bingham et al., in press). Yet, prior work has not combined the cohorts in question, nor accounted social-cultural variables such as SES, or specifically looked at interactions between SES, social context, and individual differences in brain function in predicting behavior. Given the importance of risk taking in teens, we used susceptibility to social influence on risk taking in adolescents as an important starting point for exploring interactions between SES, social context and behavior.

Operationalization of SES.

Although there exist a wide range of definitions and operationalizations of SES, we focus on parental education as our main measure of SES. We made this choice for both practical and theory driven reasons. Parental education is one of the three most common measures of objective SES (education, income, and occupation) and one that is straightforward and accurate to collect in adolescents who have not yet finished their own education and do not yet have personal incomes (they are also often unaware of their family income; (Boyce, Torsheim, Currie, & Zambon, 2006; Ensminger et al., 2000)). Parental education is known to relate to several important outcomes including correlating well with participants' own educational achievement and health outcomes (Davis-Kean, 2005; Ensminger et al., 2000). From a theoretical perspective, using parental education as a proxy for SES emphasizes a person's access to human capital; those with higher education tend to have access to both greater material (e.g., financial, affordance of healthcare and private school) (Gregorio & Lee, 2002) and nonmaterial resources (e.g., knowledge, skills, and experience) in the local socio-cultural environment (Bradley & Corwyn, 2002).

The current study

The current study examined how SES, conceptualized as a socio-cultural variable, moderates the relationship between brain activity in key networks of interest and susceptibility to social influence. More specifically, the current study examined whether one's SES background (parental education) moderated the relationship between neural networks associated with social pain (dACC+AI+subACC), mentalizing (rTPJ+DMPFC), and reward sensitivity (VS+VMPFC) during an fMRI social exclusion task (i.e., Cyberball) and risk taking in the presence of a peer who expressed risk-accepting or risk-averse norms one week later during a driving simulator session. Driving simulators provide an externally valid measure of driving behavior while maintaining a high degree of experimental control (Caird & Horrey, 2011).

Methods

Participants

Adolescent males (*N*=78) between the ages of 16 and 17 were recruited across two cohorts from the Michigan Driver License Records through the University of Michigan Transportation Research Institute as part of a series of larger studies examining teen driving behavior (Simons-Morton, Bingham, Falk, et al., 2014; Simons-Morton, Bingham, Li, et al., 2014). All participants were right-handed, did not suffer from claustrophobia, were not currently taking any psychoactive medications, had normal (or corrected to normal) vision, did not have metal in their body that was contraindicated for fMRI, and did not typically experience motion sickness, which could affect driving simulation testing. Legal guardians provided written informed consent and teens provided written assent. Finally, the sample consisted of primarily white adolescents from a similar geographic location, therefore the results associated with SES should be free from confounds with race or age.

Study design

Participants completed two appointments, consisting of an initial fMRI scan session, followed one week later by a driving simulator session. During the two sessions participants completed a series self-report measures, including a measure of objective SES (mothers' and fathers' education). During the scanning session participants completed a social exclusion task (Cyberball), while we recorded activity throughout their brains using fMRI. Finally, one week later participants completed a driving simulator session in which they drove alone and with a peer confederate. Participants were randomly assigned to drive with either a peer who expressed risk-accepting or risk-averse social norms regarding driving behavior (additional details reported in supplemental materials and in (Bingham et al., in press)).

Socioeconomic status (SES)

Fathers' and mothers' education served as our primary measure of SES. Participants were asked what level of education their father and mother had completed using a 7-point scale, where 1=less than high school, 2=high school, 3=trade school, 4=associates degree, 5=bachelor degree, 6=graduate degree, and 7=unknown. Two participants were with unknown levels of education (response=7) and were dropped from the analysis. The distribution of parental education scores can be found in table 1. Parental education was examined as a continuous variable in all analyses. Furthermore, in order to probe the relationship between our regions of interest (ROIs) and driving risk (passenger – solo drives) at higher and lower levels of SES we ran an analysis of the simple slopes at +/-1 standard deviation in order to establish whether interactions observed were driven by higher or lower SES participants.

Social exclusion (Cyberball)

Neural responses to social exclusion were measured during the fMRI scanning session using the game Cyberball (Eisenberger et al., 2003; Williams et al., 2000). During this task, participants played two rounds (178 seconds each) of a virtual ball-tossing game with two confederate participants. Participants either met two peer confederates prior to the scanning session (cohort 1) or were told that the two other people playing catch with them were other participants in the study who were being scanned at other locations on campus (cohort 2). In order to increase the plausibility of the confederate cover story participants were asked prior to the scan to create a login ID and password that would be required to start the ball tossing game. At the beginning of the Cyberball task participants were then asked to enter their password on a login screen as they waited for all study participants to login. In reality, the two other players were controlled by a pre-set computer program. Participants were instructed to throw the ball to whomever they choose. Participants were told that there is no objective other than not holding onto the ball. During the first round (inclusion) of the game, both confederate players threw the ball to one another and to the participant equally. However, during the second round (exclusion) the confederate participants threw the ball only to one another and excluded the participant (Fig1). One functional run was recorded for each participant (251 volumes). Order of the rounds was held constant to preserve the psychological experience across participants. These rounds were preceded by a period in which participants visually tracked a star as it moved on the screen (105 seconds). Each of these periods was separated by a 16 second dot-fixation rest period. Finally, participants were interviewed following the fMRI session in order to determine whether participants were suspicious of the Cyberball confederate manipulation. No participants reported being suspicious of the confederate manipulation. In addition, participants were told that they were excluded from the task due to a computer error in order to alleviate any distress due to social exclusion.

Driving risk (driving simulator)

One week after the fMRI scan session, participants completed a driving simulator appointment. During the session, participants began with a practice drive to habituate to a stateof-the-art fixed-based driving simulator. The driving simulator consisted of a full vehicle cab that was surrounded by three forward screens (120-degree view) and one rear screen (40-degree view). In order to provide a realistic experience, the driving simulator system included steering feedback, road vibration, a virtual LED instrument cluster, side-view mirrors, and simulated audio (Fig2).

Confederate manipulation. All participants then drove alone and in the presence of one of two young male confederates (randomly balanced across participants) who expressed risk-accepting or risk-averse driving norms, with the goal of each drive to get to a music concert on time. Specific details regarding the manipulation can be found in supplemental materials.

Driving risk measures. Risk measures involved decision-making at four-way intersections during changing lights. The main measures of interest consisted of the percent of time the car was in the intersection during a red light and the proportion of time a participant stopped at an intersection when the light turned yellow. Due to the high correlation (r=.93) between the two driving measures we only report on the percent of time in the intersection during a red light. Nine out of 20 urban intersection stop signals were programmed to change to yellow as the driver approached (i.e., 2.3, 2.6, or 2.9 seconds) the intersection and are the focus of the current analysis. The current analysis is focused on changes in driving risk associated with the social norms expressed by the peer passenger (risk-averse versus risk-accepting) compared to driving alone. To facilitate ease of interpretation, changes in driving risk (passenger drive – solo drive) were coded as positive when participants driving with the risk-averse passenger decreased their risk relative to driving alone, and as positive when participants driving with risk-accepting passengers increased their risk taking relative to driving alone. Thus, higher scores indicate increased conformity to the social norm expressed by the passenger.

Data Acquisition and Analysis

fMRI Data. Imaging data were acquired using a 3 Tesla GE Signa MRI scanner. Details regarding functional image collection and preprocessing can be found in supplemental materials. Data were modeled using the general linear model as implemented in SPM8. Three trial phases were modeled: social inclusion, social exclusion, and a visual tracking phase that was not used in the current investigation. These phases were modeled as blocks and convolved with the synthetic hemodynamic response as provided by SPM. The six rigid-body translation and rotation parameters derived from spatial realignment were also included as nuisance regressors. Data were high-pass filtered with a cutoff of 128s. All data were taken from the contrast social exclusion > social inclusion.

Regions of interest (ROIs). Anatomical regions of interest (ROIs) were constructed based on our a priori hypothesized regions involved in social pain (dACC+AI+subACC; Fig3), mentalizing (rTPJ+DMPFC; Fig4), and reward sensitivity (VS+VMPFC; Fig5) using MarsBar (Brett et al., 2002). Details regarding the ROI definitions can be found in supplemental materials.

Analysis plan. Data were collected across two cohorts (referred to as “cohort” in models below), therefore cohort was used as a control variable. All analyses were conducted in R (version 3.2.2). First, we examined whether differences in driving behavior were related to individual differences in SES using the equation:

$\text{Conformity}=\beta_1(\text{SES})+\beta_2(\text{drive order})+\beta_3(\text{cohort})+\varepsilon.$

Next, we examined whether exclusion during cyberball (in each of the hypothesized ROIs) were associated with SES using this general equation:

$\text{ROI}=\beta_1(\text{SES})+\beta_2(\text{cohort})+\varepsilon.$

In addition, we examined whether ROIs were associated with conforming to the driving norms expressed by the peer passenger when SES was not considered in the model:

Conformity=β_1(ROI)+ β_2(drive order)+β_3 (cohort)+ε.

Finally, planned ROI analyses included regression models, specified by the following general equation:

Conformity=β_1(SES)+β_2(ROI)+β_3(SES*ROI)+ β_4(drive order)+β_5(cohort)+ε.

Whole brain analysis

Following planned ROI analyses, we also conducted a whole-brain search to examine whether regions outside of our main ROIs were associated with driving risk, in interaction with SES and confederate behavior: Details regarding the methods and results can be found in supplemental materials. Therefore, in the following whole brain regression we focused on changes in driving risk (passenger – solo) that were consistent with the social norms expressed by the peer passenger (conformity) interacted with SES, controlling for drive order, cohort, and all lower level interactions and main effects.

Brain activity ($\text{Cyberball}_{(\text{exclusion} > \text{inclusion})}$)=$\beta_1$(SES)+$\beta_2$(passenger-solo)+$\beta_3$(confederate norms)+$\beta_4$(confederate norms*SES)+$\beta_5$(SES*passenger-solo)+$\beta_6$(conformity)+$\beta_7$(conformity*SES)+$\beta_8$(drive order)+$\beta_9$(cohort)+ε. The whole brain analysis was cluster corrected using 3dClustSim at p=.005, k>181, corresponding to p<.05, corrected.

Results

Self-report measures

Socioeconomic status. Participants reported having mothers with an average education between an associate and bachelor's degree (M=4.66, SD=1.31), ranging from having a high school diploma (2) to having a graduate degree (6). In addition, participants reported having fathers with an average education between an associate and bachelor's degree (M=4.87, SD=1.38), ranging from having a high school diploma (2) to having a graduate degree (6).

Driving risk measures

Driving conformity. Participants spent an average of 2.29% (SD=12.37%) more time in the intersection during a red light during the passenger drive compared to their solo drive ($t(74)$=-1.61, p=.113, CI=[-.05, .01]). The difference in time spent in the intersection during a red light between passenger and solo drives (passenger – solo drive) ranged from -33.40% to 33.13%, indicating that some participants drove more safely with the passenger and some less safely compared to their solo drive. In particular, participants who drove with a risk-averse confederate averaged 1.38% (SD=13.27%, min=-33.40%, max=33.13%) more time in the intersection during a red light during the passenger drive (vs. solo), whereas participants who drove with a risk-accepting confederate averaged 3.34% (SD=11.34%, min=-31.08%, max=19.77%) more time in the intersection during a red light during the passenger drive. When collapsing across cohorts, the risk-accepting and risk-averse confederate conditions were not significantly different from one another, controlling for drive order and cohort (β=.11, $t(71)$=1.00, p=.321, CI=[-.03, .08])[1], however, there was high variance in conformity, which we capitalize on below.

Driving conformity and SES. Next, we examined whether changes in driving risk (passenger – solo) that conform to the social norms expressed by the peer confederate (i.e., taking more risks when driving with a risk-accepting passenger and taking less risks when

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[1] Note: Consistent with work published by Bingham et. al. (in press), confederate norms were significantly associated with driving risk (passenger) in our second cohort when examining yellow light intersection behavior (β=-.33, $t(39)$=-2.17, p=.036, CI=[-.46, -.02]), controlling for drive order. The relationship between confederate norms and the percent of time in the intersection during a red light was marginal, controlling for drive order (β=.27, $t(39)$=1.76, p=.087, CI=[-.01, .18]).

driving with a risk-averse passenger) were related to SES, controlling for drive order, and cohort. Results indicated that SES (fathers' and mothers' education) was not significantly related to conformity during the passenger drive, $p>.05$.

Neural region of interest (ROI) analyses

Neural ROIs and SES. First, we examined the relationship between activity within ROIs previously associated with social pain, mentalizing, and reward sensitivity during exclusion and SES in order to determine whether those from different SES backgrounds showed different average brain responses to social exclusion. There were no significant differences in any of the ROIs (social pain, mentalizing, and reward sensitivity) according to SES (mother's or father's education), $p>.05$; in other words, those from high and low SES backgrounds showed similar average responses to social exclusion within our brain networks of interest.

Neural ROIs and conformity. Second, we examined the relationship between activity within ROIs previously associated with social pain, mentalizing, and reward sensitivity during exclusion and changes in driving risk (passenger – solo) associated with the social norms expressed by the peer confederate. Overall, there were no significant main effects of social pain, mentalizing, and reward sensitivity networks on driving risk, controlling for drive order, and cohort, $p>.05$.

Social pain network, SES and driving conformity. Next, examined whether the relationship between activity in the social pain network during exclusion and changes in driving risk (passenger – solo) associated with the social norms expressed by the peer passenger was moderated by SES. Results indicated that SES (fathers' education) significantly moderated the relationship between the social pain network activity during exclusion and conformity in the driving simulator ($\beta=-.60$, $t(65)=-3.96$, $p<.001$, $CI=[-.21, -.07]$; Fig6). Specifically, increased activity in the social pain network during social exclusion was significantly associated with greater conformity to the driving norms expressed by the peer passenger for those from lower SES backgrounds (β=.86, t(65)=3.18, p=.002, CI=[.09, .39]), whereas those from higher SES backgrounds were significantly less likely to conform to the driving norms expressed by the peer passenger (β=-.53, t(65)=-3.53, p<.001, CI=[-.23, -.06]). Mothers' education did not moderate the relationship between activity in the social pain network during exclusion and changes in driving risk (passenger – solo) associated with the social norms expressed by the peer passenger (β=.02, t(65)=0.15, p=.883, CI=[-.06, .07]).

Mentalizing network, SES and driving conformity. Next, SES (fathers' education) significantly moderated the relationship between neural activity within the mentalizing network during social exclusion and conforming to driving norm expressed by the peer passenger (β=-.25, t(65)=-2.34, p=.022, CI=[-.10, -.01]; Fig7). Specifically, increased activity in the mentalizing network during social exclusion was not significantly associated with conforming to the driving norm expressed by the peer passenger for those from lower SES backgrounds (β=.27, t(65)=1.41, p=.163, CI=[-.03, .16]), however those from higher SES backgrounds were significantly less likely to conform to the driving norm expressed by the peer passenger (β=-.34, t(65)=-2.07, p=.042, CI=[-.17, -.00]). Mothers' education did not moderate the relationship between activity in the mentalizing network during exclusion and changes in driving risk (passenger – solo) associated with the social norms expressed by the peer passenger (β=.09, t(65)=0.75, p=.459, CI=[-.03, .07]).

Reward sensitivity network, SES and driving conformity. Finally, SES (fathers' education) and peer influence significantly moderated the relationship between neural activity within the reward sensitivity network during social exclusion and conforming to the driving norms expressed by the peer passenger (β=-.30, $t(65)$=-3.99, p<.001, CI=[-.10, -.03]; Fig8). Specifically, increased activity in the reward sensitivity network during social exclusion was significantly associated with greater conformity to the driving norms expressed by the peer passenger for those from lower SES backgrounds (β=.57, $t(65)$=3.07, p=.003, CI=[.04, .18]), whereas those from higher SES backgrounds were significantly less likely to conform to the driving norms expressed by the peer passenger (β=-.43, $t(65)$=-2.91, p=.005, CI=[-.14, -.03]). Mothers' education did not moderate the relationship between activity in the social pain network during exclusion and changes in driving risk (passenger – solo) associated with the social norms expressed by the peer passenger (β=-.01, $t(65)$=-0.13, p=.893, CI=[-.05, .04]).

Whole brain analysis

Results from the whole brain analysis examining the changes in driving risk (passenger – solo) that were consistent with the social norms expressed by the peer passenger (conformity) interacted with SES regressed onto the contrast exclusion greater than inclusion, controlling for drive order and cohort showed significant activity in the VS, dACC, medial prefrontal cortex (MPFC), inferior frontal gyrus (IFG), and middle temporal gyrus (table 2). Results were cluster corrected at p=.005, k>181, corresponding to p<.05, corrected.

Discussion

The current study demonstrated that SES, conceptualized as a cultural factor, moderates the relationship between individual differences in neural reactivity to exclusion and conformity during peer influenced risk taking. We found that SES (fathers' education) significantly interacted with individual differences in neural activity within the social pain (dACC+AI+subACC), reward sensitivity (VS+VMPFC), and mentalizing (rTPJ+DMPFC) networks during a social interaction in which the participant was excluded to predict conformity to peer passenger driving norms (risk-accepting versus risk-averse) relative to solo driving risk in a driving simulator one week later. Specifically, we found that increased activity in the social pain and reward sensitivity networks during social exclusion was associated with increased conformity for those from lower SES backgrounds, and decreased conformity for those from higher SES backgrounds. In addition, increased activity in the mentalizing network during social exclusion was associated with decreased conformity among those from higher SES backgrounds.

Therefore, cultural background (SES) was associated with differential responses to social norms and peer pressure, such that those from lower SES backgrounds who showed the greatest sensitivity to exclusion in affective processing systems conformed to the social norm, whereas high SES behaved in opposition. By contrast, effects of sensitivity in social cognition (mentalizing) systems during exclusion were associated with decreased conformity for those from higher SES backgrounds but not related to conformity for lower SES. In past work, sensitivity to social pain, social rewards and to social cues more broadly have been implicated in susceptibility to social influence (Falk et al., 2012). The current results build on and extend this body of research by demonstrating that sensitivity within these systems is associated with different behavioral outputs, depending on cultural and situational social contexts.

These findings build upon and extend previous work demonstrating that increased sensitivity to social cues in the form of social pain are associated with differential susceptibility to peer influence among adolescence (Falk et al., 2014). These researchers argued that sensitivity to conflict and social pain within the dACC, AI and subACC during exclusion may promote preemptive steps to maintain control in other situations such as driving. Similarly, increased reward-related responses to peer presence have been associated with increased risk taking in the presence of peers among adolescents (Chein et al., 2011). In the context of exclusion, recruitment of reward regions, either to regulate negative emotions, or in the form of sensitivity to the possibility of connection during exclusion could also result in changes in risk taking in the presence of peers.

Critically, however, our data suggest that individuals from different cultural backgrounds may translate sensitivity to social cues into different downstream behavioral reactions. In the present analyses, compared to baseline levels of risk, those from lower SES backgrounds conformed to peer driving norms, whereas those from higher SES backgrounds behaved in opposition to peer driving norms. One possibility is that teens from lower SES backgrounds who are particularly sensitive to social cues may regulate their emotions by conforming to social norms and attempting to gain social acceptance through more risk taking in the presence of risk-promoting peers, and less risk taking in the presence of risk-averse peers. In other words, in participants from lower SES backgrounds, who tend to have more interdependent orientations (Kraus et al., 2012), neural sensitivity to potential exclusion may promote conformity. By contrast, those from higher SES backgrounds who are more sensitive to exclusion may self-regulate in the face of potential exclusion by asserting their independence or calling upon other social referents as resources. As such, different social contexts may be risk promoting or risk protective in the presence of peers depending on SES background.

This interpretation aligns with cultural neuroscience and psychology findings that those from cultures that vary in their emphasis on independence versus interdependence may differentially represent themselves and important others (e.g., parents; for a review, see (Kitayama & Park, 2010)) when making decisions. On average, those from higher SES backgrounds tend to be more independent or have an individualistic orientation, whereas those from lower SES backgrounds tend to have more interdependent or external orientation to the environment (Kraus et al., 2012). This cognitive orientation may help explain the differences in driving behaviors in the presence of the peer passengers. Participants from higher and lower SES backgrounds who showed greater sensitivity to social cues in Cyberball (as evidenced by reactivity within our key networks of interest) may both have acted according to this sensitivity during the simulated driving session. However, this may manifest itself differently according to cultural orientation. Those from lower SES backgrounds who showed greater sensitivity to social context in Cyberball may have been considering the opinions of external referents (e.g., social norm expressed by the peer, friends) when deciding how to drive in front of a peer (i.e., conforming to the social norm expressed by peers), whereas those from higher SES backgrounds may have been considering their behavior relative to themselves (e.g., behaved in opposition to the social norm expressed in order to display independence).

In this way, accounting for social context can unmask relationships that might not otherwise be evident. For example, in the current dataset, SES groups did not differ in average levels of activation within our neural networks of interest (social pain and reward sensitivity), but the same activations were associated with different downstream behaviors across the groups. These results suggest that although the sensitivity of social pain and reward networks was similar across different SES levels, the behavioral implications of individual differences in reactivity to social exclusion within these brain networks differs for those from different SES backgrounds. Specifically, in the presence of a risk-accepting peer those from lower SES backgrounds who showed more activity in social pain and reward sensitivity networks in response to social exclusion displayed riskier driving behaviors than when driving alone. However, in line with recent perspectives highlighting potential for such sensitivity to lead to positive outcomes as well (Telzer, 2016), low SES adolescents who showed higher social pain and reward sensitivity during Cyberball and drove with a risk-averse peer made safer decisions. Indeed, these data also highlight important findings that were not clear in previous work examining driving risk using the cohorts of data presented here; prior analyses of the first cohort's neuroimaging data did not specifically address confederate norms, and prior analyses of the second cohort's driving data did not find confederate norm (risk-averse versus risk-accepting) differences in the amount of time a participant spent in an intersection during a red light (Bingham et al., in press). These findings, in conjunction with the current results, suggest that differences in driving risk caused by the social norms of peer passengers may have been hidden by heterogeneity in SES backgrounds. Overall, this suggests a need to further consider the role that cultural and social class factors play in social and peer influence.

These results may also add to our understanding of health behavior disparities (e.g., increased smoking rates) associated with low SES communities (Hanson & Chen, 2007); if base rates of negative health behaviors are high, and lower SES is associated with greater conformity to social norms, this could result in greater propagation of negative health behaviors. An additional and compounding possibility related to social influence on risk behaviors specifically is that stress due to low SES environments may heighten neural sensitivity and increase susceptibility to risky influence (Kreek, Nielsen, Butelman, & LaForge, 2005; Porcelli & Delgado, 2009; Toledo & Sandi, 2011). Alternatively, it may be particularly adaptive for those exposed to low SES environments to conform to social influences. For example, conforming in order to maintain group harmony may increase social bonds among community members, which may help alleviate environmental stress. Though additional research is needed to determine the boundary conditions of the effects observed, this also opens the possibility for greater propagation of positive norms and behaviors across SES environments.

The results from the current study also add to a growing body of literature that has examined how social cognitive processing during adolescence relates to social influence, risk taking, and social development more broadly (Blakemore, 2008, 2012; Crone and Dahl, 2012; Pfeifer and Blakemore, 2012). Past research has suggested that increased risk taking and susceptibility to peer influence among adolescents is in part driven by asymmetrical brain development, where affective processing systems mature faster than cognitive control systems (Steinberg, 2008). However, this is only part of the story given that adolescents are not all equally susceptible to risk taking and social influence, and that susceptibility varies within individuals depending on the social context; for reviews see: (Crone and Dahl, 2012; Pfeifer and Allen, 2012; Pfeifer and Blakemore, 2012; Romer, 2010). Recent research highlights the importance of considering social context and individual differences in influencing adolescent risk-taking behavior (Crone and Dahl, 2012; Pfeifer and Allen, 2012; Romer, 2010). The current study expands on this idea and suggests that in addition to considering the social context, cultural or population-level environmental factors, such as SES, should be considered when examining adolescent risk taking and social influence, in conjunction with immediate social context (such as the influence of peers).

Limitations

Although the present data offer novel perspective on cultural moderators of brain-behavior relationships, these findings should be interpreted in the context of several limitations. First, it should be noted that results from the current study were associated with fathers' rather than mothers' education. Our data do not speak direct to why fathers' rather than mothers' education was more strongly associated with the relationship between sensitivity to social cues during exclusion and later conformity during simulated driving; however, in the current study we can speculate as to what this may mean. This may indicate that fathers' education was a stronger proxy for the overall household SES environment, including human and/or financial capital. It is also possible that father's education was a particularly potent variable given that our sample focuses exclusively on adolescent males. Fathers may serve as particularly important figures in the lives of young men (Nelson & Valliant, 1993). Further, our data emphasize the value of considering mothers' and fathers' education as a proxy for SES, given that under some circumstances, these measures diverge. Finally, parental education in the current sample did not include individuals with parents who had less than a high school diploma; thus future work should attempt to examine a wider range of education.

Conclusion

Overall, results from the current study revealed that cultural factors, such as SES, moderate the relationship between neural processing and conformity to important outcomes of interest, such as peer-influenced risk taking. These results provide evidence as to the importance of examining cultural level factors, as well as the social context when examining psychological and neurological processes and the behavioral outcomes they affect.

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Figures

Fig1.
Social exclusion (Cyberball).

Note: Participants played two rounds of a virtual ball tossing game during the initial fMRI session. During the first round (inclusion) both confederate players threw the ball to one another and to the participant equally. However, during the second round (exclusion) the confederate participants threw the ball only to one another and exclude the participant.

Fig2.
Driving Simulator.

Note: One week after the fMRI scan session, participants completed a driving simulator appointment. Participants drove alone and in the presence of a young male confederate (randomly ordered) who expressed either risky or safe driving norms.

Fig3.
Social pain regions of interest (ROI).

Note: The social pain network ROI includes the union of the dorsal anterior cingulate (dACC), anterior insula (AI), and subgenual cingulate (subACC).

Fig4.
Mentalizing regions of interest (ROI).

Note: The mentalizing network ROI includes the union of the right temporoparietal junction (rTPJ) and dorsomedial prefrontal cortex (DMPFC).

Fig5.
Reward sensitivity regions of interest (ROI).

Note: The reward sensitivity network ROI includes the union of the ventral striatum (VS) and ventral medial prefrontal cortex (VMPFC) from a large-scale meta-analysis (Bartra, McGuire, & Kable, 2013).

Fig6.
Relationship between social pain network and conformity moderated by SES.

Note: SES significantly moderated the relationship between social pain network activity and conforming to the driving norms expressed by the peer passenger. High (graduate degree), middle (bachelor degree), and low (< bachelor degree) SES were separated for visualization only.

Fig7.
Relationship between mentalizing network and conformity moderated by SES.

Note: SES marginally moderated the relationship between mentalizing network activity and conforming to the driving norms expressed by the peer passenger. High (graduate degree), middle (bachelor degree), and low (< bachelor degree) SES were separated for visualization only.

Fig8.
Relationship between reward sensitivity network and conformity moderated by SES.

Note: SES significantly moderated the relationship between reward sensitivity network activity and conforming to the driving norms expressed by the peer passenger. High (graduate degree), middle (bachelor degree), and low (< bachelor degree) SES were separated for visualization only.

Tables

Table 1. Distribution of parental education

	Mothers' Edu	Fathers' Edu
less than high school	0	0
high school	7	8
trade school	12	9
associate degree	5	4
bachelor degree	29	21
graduate degree	24	36

Note: Distribution of parental education scores (mothers' and fathers' education). Scores ranged from a high school diploma to a graduate degree and were analyzed as continuous measures.

Table 2.
Whole brain analysis

Region	**Hemisphere**	**x**	**y**	**z**	**k**	**t**
VS	R/L	-2	5	10	630	-4.24
dACC	R/L	-2	35	21	--	--
MPFC	R	17	59	3	--	--
IFG	R	41	33	12	--	--
Middle temporal gyrus	R	39	-43	-8	451	-4.02
Occipital lobe	L	-33	-95	22	184	-4.79

Note: Whole brain analysis examining changes in driving risk (passenger – solo) that were consistent with the social norms expressed by the peer passenger (conformity) interacted with SES, controlling for drive order, cohort, and all lower level interactions and main effects, regressed onto the contrast (exclusion > inclusion). Cluster corrected at p=.005, k>181, corresponding to p<.05, corrected.