Psychobehavioral Characteristics and Brain Mechanisms of Social Exclusion

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Abstract

Social exclusion undermines individuals' fundamental need to belong, exerting severe impacts on psychological and physiological well-being. According to the temporal need-threat model, the psychological and behavioral characteristics following social exclusion can be divided into three stages. The development of social media has introduced novel psychological and behavioral features to social exclusion. Recent functional magnetic resonance imaging (fMRI) studies have revealed that core brain regions within networks such as the salience network and default mode network are involved in the emotional and cognitive processing across various stages of social exclusion. Future research should be grounded in the temporal need-threat model, employ brain network approaches as methodological tools, explore the neural mechanisms of social exclusion, and predict post-exclusion psychological and behavioral response patterns.

Full Text

The Psychological and Behavioral Characteristics of Social Exclusion and Its Neural Mechanisms

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Abstract: Social exclusion impairs our basic needs of belongingness and has serious psychological and physiological effect on cognitive processes, emotional well-beings, physiological responses and behaviors. Under the framework of the temporal need-threat model, psychology and behavioral response to social exclusion can be divided into three stages. With the development of social media, new psychological and behavioral characteristics of social exclusion are presented. From the perspective of brain network, some key brain areas of default mode network, salience network and some other brain networks are involved in emotional and cognitive processes at each stage of social exclusion. Future studies should focus on the basis of temporal need-threat model to investigate the brain network of social exclusion and predict the psychological and physiological response patterns after social exclusion.

Keywords: social exclusion; temporal need-threat model; social media; default mode network; salience network

Humans are fundamentally social animals with a strong need for stable social connections throughout survival, development, and reproduction (Nezlek, Wesselmann, Wheeler, & Williams, 2012; Williams, 2007). Consequently, individuals are highly sensitive to any information that threatens these social bonds, experiencing both psychological and physiological distress when social connections are damaged. Social exclusion represents a ubiquitous phenomenon that disrupts social bonds and inflicts social pain, defined as the process by which an individual' s needs for belongingness and relationship are obstructed through rejection or ostracism by a social group or others (陈晨, 杨付, 李永强, 2017; 杜建政, 夏冰丽, 2008; Williams, 2007). Rejection and ostracism constitute two core types of social pain: rejection involves explicit refusal of acceptance, while ostracism refers to being ignored and excluded by others (Williams, 2007). Additionally, sudden experiences of social exclusion have been characterized as stressful situations that may trigger depression (Wang, Braun, & Enck, 2017).

In recent years, advances in brain imaging and neurophysiological research techniques have enabled investigators to explore the neural mechanisms underlying social exclusion by analyzing patterns of neural activity and predicting subsequent psychological and behavioral responses. Domestic scholars have previously summarized research paradigms and theoretical models of social exclusion, identifying key controversies and future methodological directions (蔡强, 吴寅, 刘金婷, 2011; 程苏, 刘璐, 郑涌, 2011; 杜建政, 夏冰丽, 2008). Subsequent research has made further progress on these controversies, yielding numerous new discoveries regarding the psychological and neural mechanisms of social exclusion. In particular, the development of brain network analysis methods has provided solutions to many previously contentious issues, such as the uniqueness and diversity of individuals' psychological and behavioral response patterns to social exclusion and the differential neural activity patterns elicited across various stages of exclusion.

However, social exclusion is a phased process, and the effects of currently experiencing exclusion, having recently experienced it, and enduring it over extended periods differ significantly. No existing literature has systematically summarized and analyzed the psychological and behavioral characteristics and neural mechanisms of social exclusion across different temporal stages. Therefore, this review builds upon the classic temporal need-threat model (Ren, Wesselmann, & Williams, 2018; Williams, 2007, 2009) to organize the impact of social exclusion into three distinct stages. By integrating recent brain network research, we examine the psychological manifestations and neural activity changes associated with social exclusion from this three-stage perspective, offering new insights for predicting post-exclusion psychological and behavioral responses.

2.1 The Temporal Need-Threat Model

Williams and colleagues integrated extensive empirical research on the psychology and behavior of social exclusion to propose the classic temporal need-threat model (Ren et al., 2018; Williams, 2007, 2009). As illustrated in Figure 1 [Figure 1: see original paper], this model comprises three primary stages: the reflexive stage, the reflective stage, and the resignation stage. Following exclusion, individuals first enter the reflexive stage, experiencing threats to four fundamental psychological needs: belongingness, self-esteem, control, and meaningful existence, accompanied by feelings of pain, sadness, anger, and low satisfaction. Subsequently, the reflective stage involves efforts to recover from exclusion through two main behavioral strategies: prosocial and antisocial behaviors. Recent research has identified an additional response—withdrawal—where some individuals simply seek relief from painful social interactions by pursuing solitude (Ren, Wesselmann, & Williams, 2016). Finally, when exclusion persists, individuals enter the resignation stage, experiencing intense feelings of alienation, depression, helplessness, and worthlessness.

2.2 New Characteristics of Psychological and Behavioral Changes Across Stages

Research findings on the reflexive stage of the temporal need-threat model have been relatively consistent, demonstrating that social exclusion obstructs fundamental needs, reducing belongingness, self-esteem, control, and meaningful existence while eliciting negative emotions. However, the reflective stage—most extensively studied in the social exclusion literature—has revealed diverse behavioral patterns. Early studies found that some individuals become more attentive to social information or more inclined to imitate others, while others choose to aggress against or punish those who excluded them. Recent research has shown that social exclusion enhances perspective-taking (王紫薇, 涂平, 2014) and theory of mind (Knowles, 2014; White et al., 2016; Will, Crone, & Guroglu, 2015). Knowles (2014) conducted a series of experiments demonstrating that social exclusion prompts individuals to shift from self-centered to other-centered perspectives, with excluded individuals exhibiting enhanced perspective-taking abilities. White and colleagues examined the relationship between theory of mind and social exclusion from a mentalizing perspective, finding that typically developing children showed improved mentalizing abilities after exclusion, using more mental state language and communicating more effectively to reestablish social connections (White et al., 2016).

Notably, Ren et al. (2016) discovered that excluded individuals in the reflective stage also exhibit withdrawal responses, seeking personal solitude. In their study, 113 participants first completed Big Five personality and Rosenberg self-esteem questionnaires before undergoing the Cyberball task—a widely used paradigm in social exclusion research. Results revealed that extraversion moderated behavioral responses to exclusion, with introverted individuals more likely to withdraw after being excluded and preferring to complete subsequent tasks alone. Researchers interpret prosocial, antisocial, and withdrawal responses as defensive mechanisms to avoid further social pain. This newly identified withdrawal response represents a "moving away" tendency that may help individuals distance themselves from threats and avoid additional suffering (Ren et al., 2016). These findings are supported by Hales et al. (2016), who demonstrated that prayer, self-affirmation, and attentional distraction can effectively reduce social pain following sudden exclusion (Hales, Wesselmann, & Williams, 2016).

When individuals experience prolonged exclusion, they enter the resignation stage, feeling alienated, helpless, worthless, and potentially depressed, ultimately leading to dysregulated cognitive and emotional capacities that affect psychosocial development. Martin et al. (2017) investigated the long-term effects of social exclusion using a sorority recruitment paradigm, measuring participants' baseline levels of depression, positive affect, life satisfaction, sense of belonging, and perceived social status before rejecting some volunteers. Remarkably, even after three months, some psychological indicators had not returned to baseline levels, demonstrating the enduring impact of social exclusion on psychological well-being (Martin, Smart Richman, & Leary, 2017). Oxman-Martinez et al. (2012) surveyed 1,053 newly immigrated children aged 11-13 in Canada, finding that one-fifth felt excluded and one-tenth felt socially isolated. Due to prolonged exclusion, many children avoided group activities, with those experiencing chronic exclusion never participating in organized activities (Oxman-Martinez et al., 2012). Social exclusion triggers depressive affect, and notably, individuals high in depression who experience exclusion may spiral further into depression, developing world-weary and withdrawal behaviors that subsequently lead to greater isolation and further exclusion (Starr & Davila, 2008).

2.3 Influence of Social Factors Across Stages

As a social phenomenon, social exclusion is influenced by situational and cultural contexts. Over the past decade, dramatic social changes—particularly internet development—have introduced new characteristics to the domains and impacts of social exclusion. The proliferation of social networking sites has led people to spend increasing amounts of time communicating in virtual spaces, with platforms like QQ, WeChat, and Weibo becoming primary social tools in China. Research indicates that online social interaction can effectively regulate loneliness, self-esteem, self-worth, and emotional states. In recent years, coinciding with the rapid development of online media, researchers worldwide have examined the relationship between online social interaction and social exclusion, investigating how virtual network exclusion affects individuals during the reflexive stage.

In domestic research, Chiou et al. (2015) divided participants into two groups: one underwent an online social networking priming task while the other completed a neutral priming task before performing the Cyberball exclusion task. Results showed that online social networking priming effectively alleviated the painful experience of social exclusion. Subsequently, they examined responses to social exclusion among different levels of online social network users by asking heavy users to recall and record feelings about being unable to use social media while control participants recorded feelings about being unable to access university websites. After mutual recognition paradigm exclusion, heavy social media users who recalled losing access to social networks reported more painful exclusion experiences (Chiou, Lee, & Liao, 2015). Lin et al. (2017) similarly found that highly anxious individuals who used social networking software after exclusion recovered well from its negative effects (Lin, Li, & Qu, 2017). International research has also demonstrated that Facebook use during exclusion can effectively reduce threats to belongingness needs (Knausenberger & Echterhoff, 2018).

Many adolescents who experience exclusion rarely express it in real life but seek belongingness online. Technological advances in social networking have enabled individuals to escape real-life situations and attempt to detach from experienced exclusion. However, research indicates that when individuals become dependent on online social interaction, leaving the network increases feelings of loneliness, creating greater dependency. Lonely individuals are more inclined to use the internet for social activities, even replacing offline face-to-face interactions (Nowland, Necka, & Cacioppo, 2018). An analysis of Facebook user activity patterns revealed that adolescents' posting, checking-in, dark content browsing, and attitudes toward online comments can predict their real-life social exclusion experiences and subsequent psychological changes and coping strategies (Ophir, Asterhan, & Schwarz, 2019). Compared to Westerners, Chinese individuals are more introverted, particularly adolescents who are reluctant to disclose exclusion experiences, potentially exhibiting more withdrawal behaviors during the reflective stage by seeking belongingness online, becoming addicted, and affecting individual development. Chronic exclusion increases depression risk and may lead to extreme online behaviors that impact real life. Therefore, analyzing adolescents' social media usage patterns may reveal changes in mental health indicators, providing new directions for psychological health education and intervention. However, current domestic research in this area is scarce and represents an important future direction.

3 Brain Network Characteristics Across Stages of Social Exclusion

Early cognitive neuroscience research primarily focused on identifying brain regions associated with psychological responses to social exclusion. Numerous fMRI studies have demonstrated that responses to social exclusion involve multiple brain regions, including the anterior cingulate cortex (ACC), posterior cingulate cortex (PCC), insula, ventral and ventrolateral prefrontal cortex (vPFC/vlPFC), and temporal lobe (Wang et al., 2017). Among these, ACC and PFC activity shows the strongest association with social exclusion but remains highly controversial. Since Eisenberger et al. first identified the close relationship between dorsal anterior cingulate cortex (dACC) and social exclusion (Eisenberger, Lieberman, & Williams, 2003), this finding has generated substantial debate.

Reviewing previous literature reveals three main controversies: First, does the widely used ball-tossing paradigm genuinely induce need threat during the reflexive stage? Researchers argue that while the Cyberball paradigm elicits strong feelings of exclusion, it also creates expectancy violation effects—participants feel not only excluded but also surprised or puzzled. This expectancy violation activates ACC regions associated with conflict monitoring, raising the question of whether dACC activation reflects conflict monitoring or exclusion experience. Meta-analyses have yielded inconsistent results regarding dACC' s contribution to social exclusion (Cacioppo et al., 2013; Rotge et al., 2015). Second, what are the neural activity patterns during the reflective stage, and can neural activity predict prosocial, antisocial, or withdrawal behaviors? Will et al. (2015) found that excluded individuals with different perspective-taking abilities showed distinct behavioral responses toward excluders, with behaviors related to theory-of-mind brain regions rather than punitive actions. Third, while literature reports that chronic exclusion produces depression and worthlessness, and that individuals exhibiting violent or suicidal behaviors show altered brain function and structure (Fossati, 2019; Olie & Courtet, 2018; Schwartz et al., 2019), how to identify and intervene in these negative effects remains underexplored.

As researchers have gained deeper appreciation for brain network functions, they have recognized that activation of individual brain regions insufficiently explains the neural mechanisms of social exclusion, prompting investigations into functional connectivity between different regions. However, no existing literature has reviewed the relationship between brain networks and social exclusion. Therefore, as illustrated in Figure 2 [Figure 2: see original paper], this section examines the neural mechanisms of social exclusion by focusing on key brain regions within the salience network (SN), default mode network (DMN), and other networks in relation to psychological and behavioral manifestations.

Figure 2 Neural activity patterns in brain networks across stages of social exclusion. The salience network primarily involves the ventral striatum, dorsal anterior cingulate cortex (dACC), amygdala, anterior insula (AI); the default mode network primarily involves the posterior cingulate cortex (PCC), precuneus, medial prefrontal cortex (mPFC), inferior parietal lobe (IPL), temporoparietal junction (TPJ); the executive control network primarily involves the dorsolateral prefrontal cortex (dlPFC); other regions include the ventrolateral prefrontal cortex (vlPFC) and ventral anterior cingulate cortex (vACC).

3.1 Salience Network

The salience network (SN) represents a crucial brain network in social cognition research, comprising bilateral anterior insula (AI), dACC, amygdala, ventral striatum, and ventral tegmental area. Additionally, the SN involves the hippocampus and dorsomedial thalamus. The SN consists of two subnetworks: the ventral attention network (VAN) and affective network (AN), primarily responsible for monitoring unexpected events and emotional processing (Kaiser, Andrews-Hanna, Wager, & Pizzagalli, 2015; Seeley et al., 2007). SN processing involves two components: first, a rapid, automatic bottom-up process that detects and filters external information, particularly salient information such as potential threats—this biologically innate processing is evolutionarily crucial; second, a high-level command system that integrates perceptual, emotional, and other cognitive information and transmits it to functionally relevant brain regions (Goulden et al., 2014; Menon & Uddin, 2010). The anterior insula in the SN system is primarily involved in socio-emotional processing such as pain, introspection, empathy, and disgust, while dACC is primarily involved in response selection and conflict monitoring.

However, recent neuroimaging studies have found that dACC activation during the reflexive stage of social exclusion reflects painful experiences of thwarted needs, sharing common neural mechanisms with physical pain (Eisenberger et al., 2003; Eisenberger, 2012, 2015b; Kross, Berman, Mischel, Smith, & Wager, 2011). Eisenberger conducted quantitative reverse inference analyses and meta-analyses on 10,000 fMRI studies from the Neurosynth database, establishing that only pain processing showed high correlation with dACC activation, while executive, conflict, or salience processing showed no significant correlation (Eisenberger, 2015a; Lieberman & Eisenberger, 2015). Nevertheless, many researchers have challenged this view, arguing that dACC participates in numerous cognitive control processes, and that claiming dACC activation is unrelated to non-pain processing contradicts extensive SN research findings. They contend that using dACC activation as an index of social exclusion pain represents a misguided approach (Iannetti & Mouraux, 2011; Iannetti, Salomons, Moayedi, Mouraux, & Davis, 2013; Wager et al., 2016). This debate remains unresolved, but alternative approaches may help: given that anterior insula serves as a key SN node closely related to pain, empathy, and disgust, and dACC is associated with social pain, examining connectivity changes between these regions and others may provide evidence to address these controversies.

Behavioral studies have reported reduced self-control and impulse control during the reflective stage of social exclusion. Social exclusion activates bilateral anterior insula and amygdala—critical regions for emotional processing. Since AI shows strong connectivity with dACC and middle anterior cingulate cortex (mACC) in brain networks, AI activity changes subsequently affect dACC and mACC regions involved in self-awareness and cognitive control (Martelli, Chester, Warren Brown, Eisenberger, & DeWall, 2018; Wang et al., 2017). Another study comparing different types of social exclusion suggested that dACC activation during negative feedback in social evaluation tasks primarily reflects conflict detection (discrepancy between expectations and actual feedback), whereas in ball-tossing paradigms, it primarily reflects painful experience. Additionally, social exclusion pain correlates negatively with vlPFC activity, while ventral striatum can modulate activation levels in pain-related brain regions (Premkumar, 2012). This emotion-cognition circuit demonstrates the impact of social exclusion on cognitive function at the neural level but insufficiently explains why individuals adopt different behavioral patterns, requiring further research support.

Furthermore, racial discrimination represents a special type of social exclusion. Behavioral research indicates that individuals living in chronically discriminatory environments also exhibit resignation states and even depression. Berger et al. (2015) reviewed fMRI studies on racial discrimination-related social exclusion, finding that perceived exclusion activated many core SN regions. Specifically, racial discrimination events enhanced functional connectivity between amygdala and dACC as well as AI (Berger & Sarnyai, 2015). In social exclusion involving racial discrimination, discriminatory acts serve as salient stimuli that affect SN regions. Dysregulated activation and abnormal connectivity in SN regions may lead to heightened sensitivity to exclusion events such as racial discrimination.

As a crucial brain network responsible for detecting and filtering external information, SN plays an important role in social cognition. Current research confirms that dACC participates in social exclusion processing to some extent, but this does not mean dACC is exclusively sensitive to social exclusion, nor that its activation level serves as an index of exclusion pain severity. Future research must incorporate dACC into more specific networks related to social exclusion to accurately delineate its function. Different types of individuals, such as those in different stress states, may show different SN network responses, including dACC activity. Therefore, directly attributing dACC activation changes to social exclusion-induced pain requires further validation.

3.2 Default Mode Network

In neuroscience, the default mode network is also called the default network or default state network. When individuals perform external cognitive tasks, certain brain regions show deactivation; when at rest without external tasks, these regions return to baseline activation. The network composed of brain regions showing negative correlation between activation and task demands constitutes the DMN (Raichle et al., 2001). Core DMN regions include PCC, precuneus, and medial prefrontal cortex (mPFC). Each core region is closely associated with spontaneous internal mental activity: PCC is involved in self-processing, unconscious recall, and future imagination; mPFC is the primary region for theory of mind, responsible for perspective-taking. Additionally, DMN contains two subsystems: the dorsal medial prefrontal cortex (dMPFC) subsystem includes bilateral lateral temporal cortex (LTC), temporal pole, and temporoparietal junction (TPJ); the medial temporal lobe (MTL) subsystem includes posterior inferior parietal lobe (pIPL), ventromedial prefrontal cortex (vMPFC), and hippocampus. These subsystems play important roles in social cognition (Andrews-Hanna, 2012).

A major controversy in social exclusion research using ball-tossing paradigms concerns whether ACC activation reflects social exclusion pain or rule violation. According to the temporal need-threat model, if individuals merely perceive rule violation without entering the reflexive stage and experiencing pain, social exclusion would not produce painful effects. Addressing this issue, Bolling et al. (2011) modified the social exclusion ball-tossing task to create two conditions: social exclusion and rule violation, examining the relationship between social exclusion and social pain and ACC' s role. Based on Damasio' s emotion theory, they conceptualized social exclusion-induced emotions as two-stage processes: first, innate primary emotions involving the limbic system; second, emotions requiring greater cognitive involvement and evaluation. Results showed that ventral anterior cingulate cortex (vACC) activation reflected first-stage emotions, while dACC activation reflected second-stage emotions. To clarify vACC' s role in social exclusion, the researchers used vACC as a seed region in psychophysical interaction analysis (PPI) to examine functional connectivity changes between brain regions during different mental activities. During social exclusion, functional connectivity from vACC to mPFC, right IPL, and precuneus—core DMN regions—significantly increased. During rule violation, connectivity from vACC to precentral gyrus, bilateral insula, and paracentral lobule significantly increased. These findings suggest that during social exclusion in ball-tossing tasks, individuals may consider why they are being excluded from others' perspectives or engage in mind-wandering or imagination, resulting in heightened DMN activation and enhanced vACC-DMN connectivity (Bolling et al., 2011). Previous research has found that vACC-DMN functional connectivity relates to emotional processing, with stronger connectivity in individuals with negative affect (Greicius et al., 2007), and that vACC is closely associated with social evaluation (Rigney, Koski, & Beer, 2018). Examining vACC connectivity with DMN regions provides strong evidence that ball-tossing tasks effectively manipulate social exclusion, inducing reflexive stage responses, social pain, and corresponding brain activation and DMN connectivity changes. However, this study did not identify differences in dACC, a region more closely associated with social exclusion, across the two tasks or its role in brain networks, requiring future investigation.

The reflective stage of social exclusion shows diverse behavioral responses. Moor et al. (2012) conducted an fMRI study examining brain network activity during social exclusion across three age groups of children and adolescents and its correlation with fair behavior in subsequent Dictator Games. All age groups showed reduced prosocial behavior after exclusion, with the degree of reduction significantly correlated with activation in superior temporal sulcus (STS), lateral prefrontal cortex (lPFC), and TPJ within the DMN (Moor et al., 2012). Subsequently, Will et al. (2015) used a similar procedure, scanning participants during both Cyberball and Dictator Games to examine correlations between social exclusion and subsequent punishment or forgiveness behaviors toward excluders and their neural correlates. Results showed that activation in TPJ and mPFC within the DMN negatively correlated with antisocial behavior after exclusion; individuals with lower TPJ and mPFC activation were more likely to forgive excluders (Will et al., 2015). TPJ and mPFC are important brain regions for theory of mind, and this study provides neural support for the reflective stage of the temporal need-threat model, demonstrating that activation levels in theory-of-mind regions are closely related to behavioral outcomes following exclusion. The reflective stage is currently the most studied phase with the richest findings, and examining related cognitive abilities is key to predicting the impact of social exclusion on subsequent behavior, holding important practical significance for healthy development in children and adolescents.

Some studies have specifically examined the effects of long-term social exclusion, such as inducing loneliness. When individuals' social relationships fail to meet expectations over extended periods, they enter the resignation stage of the temporal need-threat model, experiencing loneliness and negative emotions including depression, tension, and anxiety. Che et al. (2014) investigated the relationship between social support and DMN using large-sample data from 333 participants who underwent resting-state fMRI scans and completed the Perceived Social Support Scale and Loneliness Assessment Scale. Seed-based functional connectivity and classical spectral analysis revealed that participants with higher perceived social support scores showed significantly enhanced connectivity and synchronicity between DMN regions including PCC, precuneus, IPL, and PFC (Che et al., 2014). This study demonstrates that enhanced connectivity and synchronicity within DMN regions are associated with interpersonal relationship development. If individuals experience chronic exclusion and loneliness, connectivity and synchronicity among these DMN regions decrease. As one of the most important networks during rest, DMN is closely related to emotion and behavior, and DMN impairment may induce withdrawal behaviors and interpersonal relationship disorders.

In summary, numerous core regions within the DMN are involved in emotional and cognitive processing related to social exclusion, and DMN connectivity changes in individuals with chronic exclusion experiences. Although brain network research has yielded some findings, further enrichment is needed. Current evidence, while insufficient, suggests that examining functional connectivity between vACC and DMN regions may help clarify ACC' s role in social exclusion, representing a key future research direction. Additionally, connectivity strength within DMN and between DMN and other networks may predict individual loneliness levels and behavioral responses to social exclusion. Future research should integrate key brain regions identified under different experimental conditions with DMN to more systematically and comprehensively explore the cognitive neural mechanisms of social exclusion.

3.3 Other Related Networks

Some studies have examined the impact of social exclusion on connectivity between different networks. Clemens et al. (2017) collected resting-state fMRI data before and after social exclusion, investigating connectivity changes between SN and DMN. Results showed enhanced connectivity between DMN and SN nodes such as dACC, suggesting that after social exclusion, individuals shift from spontaneous, self-referential internal mental state processing in DMN to more alert and attentive processing modes in SN (Clemens et al., 2017). However, this study did not directly examine connectivity changes during the exclusion experience, and the post-exclusion stress state may have returned to baseline, requiring further validation.

Beyond SN and DMN, social exclusion involves brain regions in other networks such as the executive control network (ECN), which primarily includes dorsolateral prefrontal cortex (dlPFC), mPFC, and IPL. ECN is closely related to emotional processing and inhibitory control, with activation levels and connectivity changes effectively reflecting social exclusion pain. Onoda et al. (2010) used fMRI to examine connectivity changes during the reflexive stage in high and low self-esteem individuals. Low self-esteem participants reported greater pain after exclusion and showed positive functional connectivity between mPFC and dACC, whereas high self-esteem participants showed negative connectivity (Onoda et al., 2010).

Some studies have explored how real-life early social exclusion experiences affect human brain functional networks, such as ACC-PFC networks. Research found that children with early separation experiences showed stronger pain responses during Cyberball, with lower activation in dACC and dlPFC and reduced dACC-dlPFC connectivity, indicating that social exclusion experiences alter social-emotional processing brain networks (Puetz et al., 2014). Additionally, a repetitive transcranial magnetic stimulation (rTMS) study applied 1 Hz continuous pulse stimulation to dlPFC during Cyberball, finding that high personal distress trait participants showed enhanced pain experience, while low personal distress trait participants showed no such effect, clarifying dlPFC' s function in the social pain network as reflecting individual pain experiences (Fitzgibbon et al., 2017). Another fMRI study found that recent social exclusion experiences affect ACC-PFC networks. Park et al. (2016) screened high and low exclusion-experience children using questionnaires and recorded brain activity during an emotional feedback task. Dynamic causal modeling analysis revealed that high exclusion-experience children showed vlPFC-ACC connectivity that suppressed responses to positive emotions while enhancing responses to negative emotions, demonstrating that vlPFC-ACC networks reflect the impact of social exclusion experiences on emotional processing (Park et al., 2016).

ACC-PFC connectivity research indicates that this network' s connectivity is closely related to social exclusion experiences, with alterations occurring both during exclusion tasks and other emotional tasks in individuals with real-life exclusion histories. However, the specific role of dlPFC activation alone in social exclusion remains unclear and requires additional research support.

4.1 New Psychological and Behavioral Characteristics of Social Exclusion: Implications for Future Research

Recent research reveals that with the development of network and social technologies, individuals increasingly rely on online social interaction to escape real-life social pain, particularly among adolescents. People now tend to express negative emotions following exclusion through social media platforms like QQ, WeChat, and Weibo, with some even expressing suicidal intentions. Additionally, internet development has introduced new forms of social exclusion, with online discrimination and exclusion triggering various forms of cyber violence that have exploded as social problems, yet few social exclusion studies have addressed this domain. Future research should leverage these media platforms to develop reliable and valid questionnaires or experimental paradigms based on information students express on social media, building upon existing research to identify which students are experiencing social exclusion and which stage they are in. These tools could provide school mental health professionals with operational screening criteria to accurately and promptly identify students suffering from social exclusion and provide psychological counseling and intervention.

Recent research has also identified another behavioral response pattern following exclusion: seeking solitude. Compared to Westerners, Chinese individuals are more introverted, and this cultural characteristic leads many Chinese adolescents to withdraw when experiencing social exclusion. Recent school bullying incidents reported online show that almost all victimized students chose to remain silent rather than respond appropriately. With similar events occurring daily, their withdrawal behaviors prevent timely identification of psychological problems and effective intervention. Future research must fully consider Chinese personality characteristics and cultural contexts to deeply explore this issue and provide guidance for domestic school mental health education and related professionals.

4.2 Brain Networks: New Directions for Social Exclusion Mechanism Research

Past controversies regarding social exclusion neural mechanisms may gradually find resolution through brain network approaches. Future research should continue addressing several major debates: First, how to construct a complete brain mechanism model of pain experience when social exclusion induces need threat. Studies should utilize existing technologies such as ERP, fMRI, and fNIRS, combined with different exclusion paradigms (ball-tossing, chat room, mutual recognition, and gaze paradigms) for cross-validation to obtain reliable, comprehensive results. Network analysis methods across temporal and spatial scales should more accurately localize brain activity at different exclusion stages, exploring social pain-related neural mechanisms through connectivity changes, particularly ACC alterations across stages, to resolve long-standing debates about ACC' s role in social exclusion. Second, current brain network research only reflects neural activity after behavioral responses in the reflective stage. Future studies should fully utilize exclusion paradigms, particularly ostracism and rejection paradigms, to examine how different exclusion types affect subsequent cognitive processing, obtaining multiple cognitive-behavioral patterns across exclusion stages to elucidate underlying neural mechanisms and predict behavioral outcomes from neural activity patterns. Third, social exclusion triggers diverse psychological problems with extremely complex neural mechanisms. More effective paradigms or analytical methods are needed to examine psychological mechanisms of behavioral responses across exclusion stages, such as investigating neural activity changes related to early-stage emotional processing, then examining brain network specificity during different post-exclusion tasks to identify neural activity changes associated with individual exclusion experiences.

Furthermore, individual social networks and brain networks may be integrated in future research. Studies have found that connectivity changes in theory-of-mind brain networks after exclusion are closely related to the number of friends in individuals' social networks. Researchers have proposed network neuroscience, integrating social cognition and neuroscience (Bassett & Sporns, 2017; Bassett, Zurn, & Gold, 2018; Falk & Bassett, 2017; Schmalzle et al., 2017), suggesting that social and brain networks can be combined through specific methods. By obtaining individuals' social network information through questionnaires and social media and combining it with brain network data from laboratory studies, social cognitive neuroscience can be conducted from a more comprehensive perspective to address questions raised by social psychology for cognitive neuroscience. This perspective requires substantial research for validation but likely represents an important direction for social cognitive neuroscience development. Future research should fully utilize network analysis methods to integrate psychological, behavioral, and neuroimaging data, constructing more systematic network models across different data dimensions to provide insights for exploring social exclusion mechanisms and developing interventions.

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