Title

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Abstract

Past research regarding the “social brain network” (SBN)—including the bilateral temporoparietal junction (TPJ), dorsomedial and dorsolateral prefrontal cortex (dmPFC and dlPFC), and precuneus— suggests that information processing in social groups impacts the behavior and actions of individuals. Current social neuroscience research illustrates that the exact functions of the SBN and its mechanisms in social versus non-social contexts is still largely a mystery. The study by Lugrin et. al (2023) concentrates on studying the SBN in a purely non-social context: aiming to investigate the distinction between neural activity in the SBN when a participant is given an intuitive or easily noticeable task, versus a less easily identifiable task– also known as a salient versus alternative stimulus. They concluded that there was higher brain activity in the TPJ and other areas of the SBN when salient configuration mapping were presented, showing the relevance of the SBN in mapping tasks related to concepts and high-level abstractions. This paper focuses on replicating and extending the given behavioral data, confirming the design of Lugrin et al. (2023)’s study and building on this foundation to explore the variations in SBN activation during different forms of social engagement. We extend this original investigation to compare the effects of different kinds of salient stimuli from online social interactions on social media with those from face-to-face social interactions, in order to discern the differences in SBN activation. This exploration aims to unravel the intricacies of SBN activation by addressing the question: Does socialization through social media engage the same neural networks, specifically in the SBN, as face-to-face interaction, and can it act as an adequate substitute for in-person socialization? To address this question, we examine groups in social isolation who predominantly use social media for interaction, as well as groups who engage in regular socialization using both social media and face-to-face interactions. Additionally, we investigate age-related differences in social media usage and its impact on SBN activation.

Keywords: Social Brain Network, Social cognition, Social media, Social neuroscience, Social interaction, Amygdala, Dorsomedial prefrontal cortex, Dorsolateral Prefrontal cortex, Bilateral Temporoparietal Junction, Anterior Cingulate Cortex, Posterior Superior Temporal Sulcus, Social isolation, Salience, Salient mappings, Pattern recognition

Introduction

The Social Brain Network, or SBN, refers to the structures of the cortex that are responsible for integrating multi-dimensional layers of information and socio-cognitive functions dealt with in daily life, such as attaching an emotion to a resting facial structure. This network is mainly made up of the posterior superior temporal sulcus (pSTS), the temporo-parietal junction (TPJ), the amygdala, the temporal poles, the medial prefrontal cortex (MPFC), and finally the anterior cingulate cortex (ACC) (Frith, 2007). The SBN is responsible for functionality inside and outside of the social sphere. Within the social sphere, it helps us understand how we process interpersonal interactions. On the other hand, examining how it functions independently of the social sphere can reveal how the SBN aids in individual cognition, behavior patterns, and emotional processing.

Previous research has suggested that there are distinct networks within the SBN responsible for: 1. Theory of Mind; the understanding that other individuals have separate and distinct mental states that are different from your own (Kanske et al. , 2015), and 2. empathy; the ability to understand and share feelings for other people (Kanske et al. , 2015). While the circuitry for the Theory of Mind is believed to be found within the TPJ, the necessary components for empathy reside in the anterior insula (Kanske et al. , 2015). Theory of Mind is important because it aids in interacting with and understanding other human beings (Elsabbagh & Johnson, 2016). In specific cases like autism spectrum disorder (ASD), there are small, localized deficits within the SBN, which explains why some children with this disorder have difficulty with theory of mind. Additionally, previous fMRI studies have found that the TPJ plays a significant role in social processing tasks, such as attention and language, which have established links with ASD.

Otherwise, individually labeling the SBN's circuits and networks leads to different theories regarding its functionality and purpose. For instance, one theory is that the SBN grew from an evolutionary standpoint and with the need of growing socialization and specialized social roles. This theory primarily operates under the assumption that the growing size and complexity of social groups necessitated more efficient structures within the SBN to accommodate this scaling. One criticism of this theory is that it only pertains to social contexts instead of overarching cognition that undermines social functionality. The other opposing theory is often called the domain-general theory, and it proposes that our brains are born with pre-existing structures to broadly interpret information (Mitchell, 2009). This is the case when the TPJ region activates during language processing as the streams responsible for language and social processings intersect, reflecting how the formation of social context occurs through the convergences of numerous functions (Smith et al., 2020). This theory is responsible for the SBN's ability to accommodate varied amounts and types of information into salient configurations, which is the core of our experiment. Unlike the evolutionary theory, this theory states that SBN functionality can be applied to non-social contexts and more informationally based processing systems, suggesting that social tasks are just a specific subset of the SBN's overall responsibilities. The theory will serve as a stepping stone for our experiment as we deviate from the fundamentals of SBN's processing ability to further examine the differences in SBN response between contrasting stimuli.

Our specific focus is to identify the functional differences when the SBN is presented with a salient configuration versus an alternative stimulus. A salient configuration is a specific grouping of items under a common theme. For instance, a phone's interface enables users to organize applications into folders, where each folder is responsible for accomplishing a broad task, such as ‘social media’ or ‘games’. This would be noted as the salient configuration because it is the most intuitive, readily thought of, and easily seen. Salient configurations are a critical notion for the SBN because it’s responsible for understanding complex social environments. A salient configuration mirrors this atmosphere of social relationships and hierarchies with arbitrary stimuli, noting how the brain processes collections of elements and information. This is necessary for the brain to have more efficient and concise processing to meet the growing demands of increased socialization. Conversely, an alternative configuration is the less instinctual response. For example, one may also organize their phone applications alphabetically, which is an ordering nonetheless but arguably not the most functional or efficient. The alternative configuration is usually more challenging to visualize than the salient configuration, yet both achieve the desired goal of ordering a collection of elements.

To investigate how the social brain network processes salience-based information, we compiled research papers published between 2013 and 2023 sources from Google Scholar and UC Campus Berkeley Library into a literature chart. We developed an extension by utilizing our initial literature chart, a collection of articles on the social brain network and salience. From our compiled articles, we decided to refine our search and evaluate Lurgin et al. (2023) hypothesis that activity in the social brain network, particularly the temporoparietal junction and prefrontal area, is associated with registering salient and alternative stimuli through a replication and extension study.

Methods

Participants

The researchers recruited 57 healthy volunteers, composed of 33 females and 24 males, aged between 19 and 35 years (M = 24.4). All participants were right-handed, medication-free, and had natural or corrected visual modalities from the Department of Economics at the University of Zurich. However, only 54 were eligible for the study because significant motion was detected during three volunteers' fMRI scans.

Task Design

The researchers utilized non-social numeracy paradigms, patterns of numbers that are inherently nonsocial with varied input configurations. Both sets contained identical stimuli but two different conditions, as subjects' tasks varied from focusing on salient mappings (salient representation of stimuli), to alternative mappings (non-intuitive representation). The two alternative accounts enabled the researchers to identify a potential difference in SBN activity when subjects are presented with salient and alternative mappings. To control for contextual updating's possible influence on SBN activity, the types of contextual switches between stimulus and response mappings were varied between blocks of trials.

On the computer, subjects continuously observed clouds of elements. The two stimulus conditions evaluated included a salient condition where participants select the cloud with the most elements and an alternative condition where participants indicate which cloud had the most significant number of a specific component (squares or diamonds). The two response conditions included salient mapping, where subjects pressed a button once to choose the first cloud and twice to choose the second cloud, and alternative mapping, which reversed the first condition. The researchers examined the participants' brain activity using a 3T fMRI during the tests.

To evaluate the results of Lurgin et al., we reviewed their methods and obtained their data from osf.io to conduct a replication study. We replicated six plots from Figure 2 of the original experiment using RStudio and utilizing the dplyr, ggplot2, readr, and ggforce packages. To replicate the data, we utilized RStudio to visualize our plots, revealing response time and accuracy in salient versus alternative stimuli, stimulus discriminability, and developing response time and accuracy throughout blocks of trials of the same condition. We developed an extension by utilizing our initial literature chart, a collection of articles on the social brain network and salience.

Replication Methods

6 plots were created in R studio for replication. The dataframe was taken from the original Lono and Konovol (2022) dataset in order to replicate the data analysis and data visualization. The replication analysis focused on generating data visualizations to represent the data and its findings.

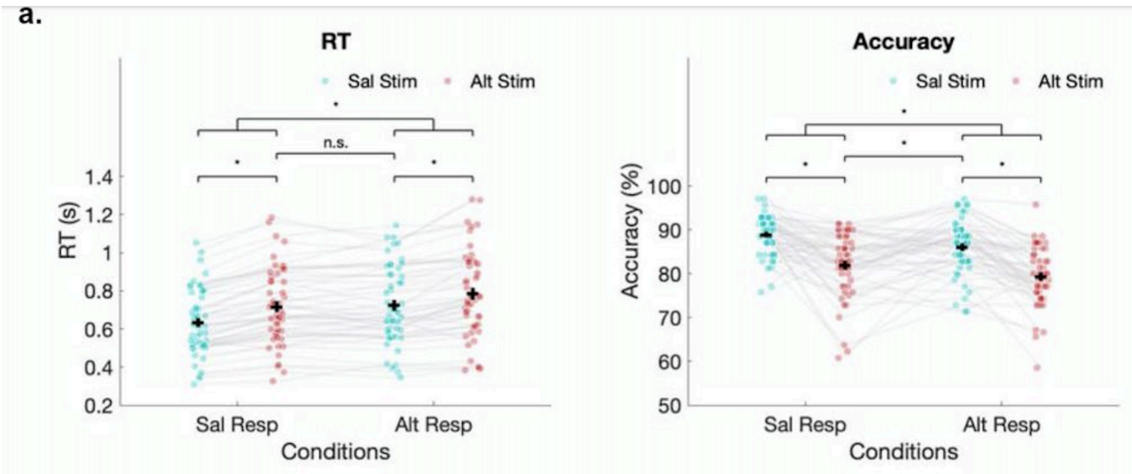
Firstly, libraries ggplot2, dplyr, readr, and ggforce were installed in R Studio in order to perform the data analysis and visualization. Dplyr alongside other packages in R were used to manipulate the data frame. The objective was to analyze any significant differences when participants were presented with different conditions. Ggplot2 and ggforce functions were used to create the following data visualizations to visualize significant differences between salient and alternative conditions.

A series of data visualizations were generated to visualize the distribution and means of participant response time and accuracy for each group. In the first two figures [A, B], scatterplots were generated to examine the effects of salient vs. alternate response type and salient vs. alternate stimulus difference. In the final figure [C], a graph was generated to examine the effects of response switching or changing response type.

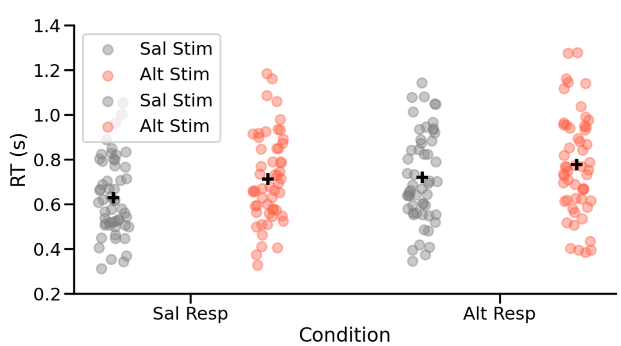
Replication Results

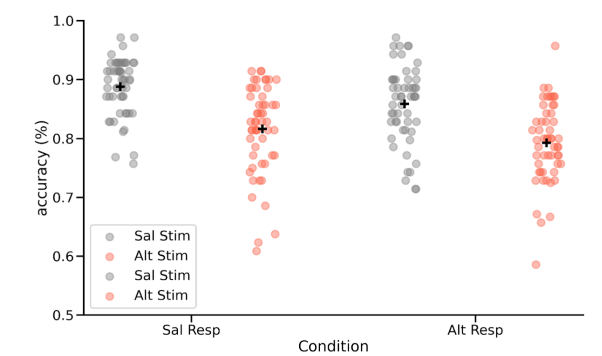
Figure A: Response time and accuracy in salient vs. alternate stimuli.

Lugrin et. al plots:



Replicated Plots:



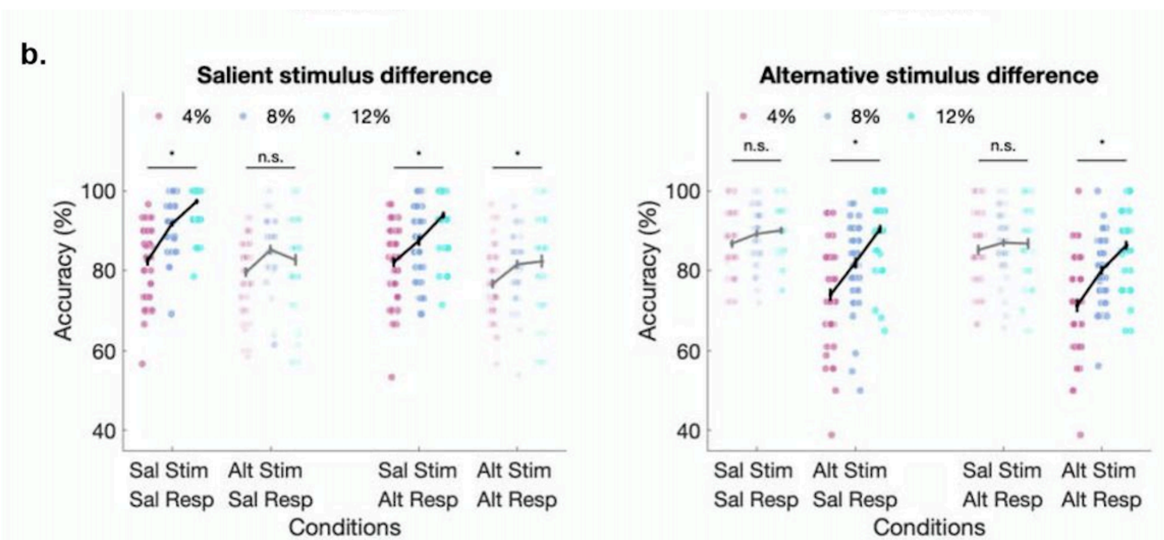


Note. Response time and accuracy in salient vs. alternate stimuli. The left scatterplot displays the response times of two conditions, salient response and alternative response, under two types of stimuli, salient stimuli and alternate stimuli. The scatterplot on the right shows the percentage of correct responses and highlights significant differences between the groups using asterisks and brackets.

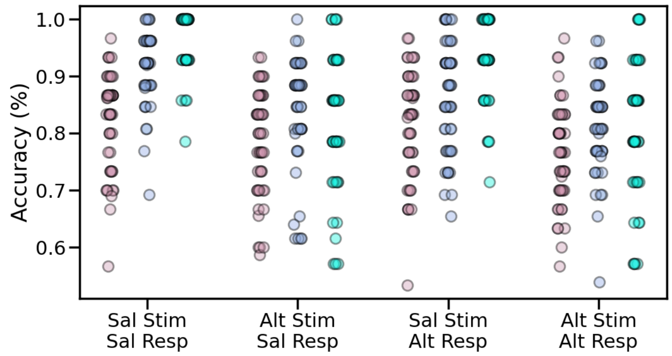
The results show that task difficulty proved more difficult for alternative stimulus in both response time and accuracy. Accuracy decreased, and RT increased in the alternative stimulus compared to the salient stimulus condition, for both salient (Accuracy: - 6.9%; RT: + 83ms) and alternative responses (Accuracy: −6.7%; RT: +64 ms), showing that the salience in the stimulus and response mappings were independent. The experimental design was validated and confirmed to create matched salient and alternative mappings.

Figure B: Stimulus discriminability with accuracy (%) and salient stimuli/response vs. alternate stimuli/response.

Lugrin et. al plots:



Replicated plots (Salient Stimulus Difference):



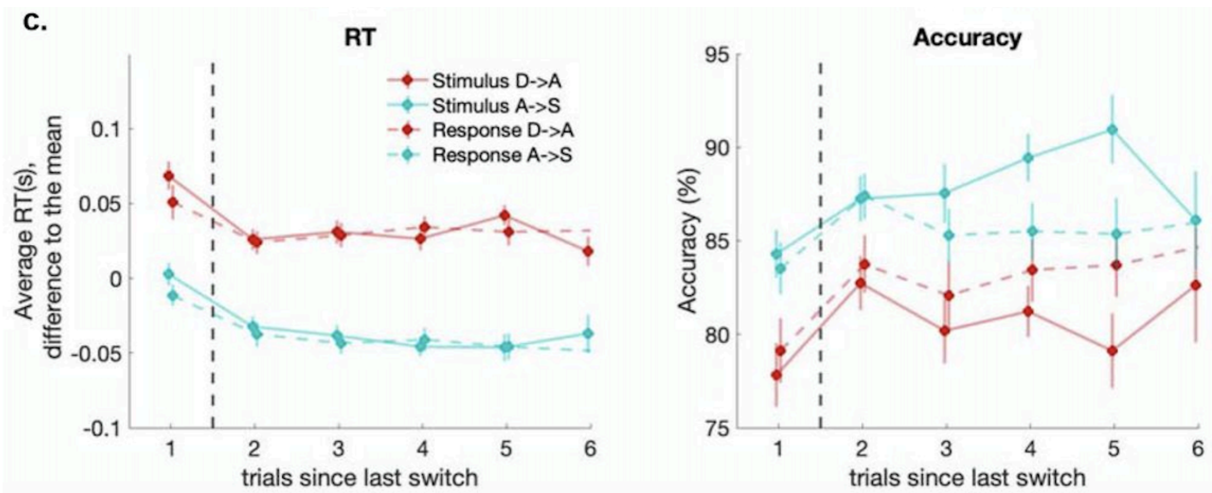
Note. display the accuracy of the three levels of stimulus discriminability for each stimulus mapping. The stimulus differences of 4%, 8%, and 12% relate to the difference of elements in the two clouds (4% being the most similar, and 12% being the most different). The representation includes two plots, one for each condition. The first plot is for the salient stimulus condition, which indicates the difference between the total number of elements in the cloud, on the left. The second plot is for the alternative stimulus condition, which indicates the difference between the number of alternative stimulus elements, such as squares or diamonds, on the right. Each dot represents one subject. Error bars show s.e.m. Upper lines and stars indicate significance ($p < 0.05$) of linear regressions between accuracy and discriminability levels.

The left plot suggests that as the salience difference increases from 4% to 12%, the accuracy increases for Sal Stim & Sal Resp (Accuracy: +9%, +6%) and Sal Stim & Alt Resp (Accuracy: +5%, +7%). Accuracy does not consistently increase with salience difference for Alt Stim & Alt Resp and Alt Stim & Sal Resp, with comparable accuracy for 12% and 4% salience difference.

The plot on the right shows a less obvious trend, as some differences in salience are not significantly affecting accuracy (indicated by "n.s." which stands for "not significant"). This suggests that the difference in saliency between the alternative stimuli does not have as clear of an impact on accuracy as the salient stimuli. However, there was a significant increase in percentage for Alt Stim & Sal Resp (Accuracy: +5%, +8%), and Alt Stim & Alt Resp (Accuracy: +9%, +6%).

Figure C: Response Switching [D: dominant (salient), A: alternative (non-salient)]

Lugrin et. al plots:



Note. The graphs depict response time (left) and accuracy (right). The findings indicate that 1) switching between stimulus and response has similar "costs", and 2) switching to alternative mappings results in more significant "costs" (i.e., decreased accuracy) than switching to salient mappings. The graph displays the evolution of response time and accuracy over blocks of trials of the same condition.

Stimulus switches are depicted using plain lines, while response switches are represented using dashed lines. The color scheme indicates the direction of the switch: red lines show switches from salient to alternative mappings, while blue lines indicate switches from alternative to salient mappings. The error bars in the graph represent the standard error of the mean (s.e.m.).

These plots analyze the concept of "response switching", which refers to the change in stimulus or response salience. For the average response time, alternative response/stimuli produce similar costs as stimulus. When it comes to accuracy, switching to salient mappings is less costly than switching to alternative mappings, which decreases accuracy the most.

Replication Discussion

Lugrin et. al's research tested SBN activation in a non-social task setting, with the conclusions of the experiment determining that the SBN can be active not only in social environments, but also in non-social contexts, specifically expressing more activation in conditions that require examining salient stimuli. They found that the SBN was involved in mapping sensory information onto high-level configurations and was more active when the task required subjects to focus on salient configurations. This salience-based effect was specific to stimulus integration and did not reflect task difficulty or contextual updating.

These findings support the domain-general theory of SBN function. One possible conclusion from this study is that the SBN is commonly activated during social situations because navigating the social atmosphere often involves cognitive processes such as pattern recognition, or the identification and comparison of various salient stimuli– for example, identifying a familiar face in a crowd, or understanding the facial and gestural expressions of characters in a movie. These are not effortful processes, but rather salient and automatic interpretations by the brain. This suggests an alternate use for the SBN: the ability to integrate multiple pieces of information into conceptually salient representations of world states that are used to guide behavior.

Overall, the results of Lugrin et. al's experiment proposes a new lens through which to examine the function and mechanisms of the SBN. These findings also hold significant implications for future social neuroscience research and experimental design, as this can help aid future research in controlling for the variety of functions of the SBN– future studies in this field should be careful in considering differences in configurational salience when designing tasks relating to SBN activation.

Extension Methods

Going forward, to reinforce the results of Lugrin et. al's research and advance current knowledge about the mechanisms of the SBN, one possible future direction may be to examine salience-based stimulus mappings in social stimuli and compare this to non-social stimuli. In the following section, we will deviate from looking at SBN activation exclusively in non-social tasks and delve into the variations in the activation of the SBN during social engagement.

We will investigate SBN activation during two kinds of social interaction: online and offline interaction. We are interested in examining cases of extreme social isolation, in which individuals rely significantly on online social platforms such as social media or texting for their social interaction, comparing SBN activation in this condition to a control condition of regular face-to-face interaction. To answer this question, we will examine specific case studies of social isolation, for example, the COVID-19 pandemic quarantine or social isolation in the elderly neurodegenerative population. Through these case studies, we also aim to investigate the presence of age-related differences in SBN activation patterns in response to excessive social media usage and social isolation. The research question that we are investigating is: "Does the SBN exhibit similar behaviors during online and offline social interactions, and does this change in a setting of social isolation when an individual receives their socialization through only online interactions?". We hypothesize that socialization through social media will not be sufficient to activate the SBN to the same degree as in-person socialization.

Extension Results

Social Isolation In COVID-19

The COVID-19 pandemic restricted social interaction through the implementation of social distancing and quarantining. Social isolation is distinguished from the subjective feeling of loneliness since it pertains to a lack of social relationships. Reduced social contact has been observed to increase mental health issues such as anxiety and depression, decreasing overall well-being. Several recent studies have found that prolonged social isolation has structural, connectivity, and activation differences in certain brain regions responsible for theory of mind (TOM), social cognition, self-referential processing, detecting and processing salient stimuli, and empathy. Taherizadeh et. al (2021) found a correlation between social isolation and hippocampal abnormalities, affecting cognitive functioning and learning, and memory behavior. Courtney and Meyer (2020) used fMRI imaging to study how participants' medial prefrontal cortex, mPFC, involved in self-perception and identity, reacted to a task where they were asked to think about the people closest to them and indicate their closeness to these people. Those with less social contact showed changes in how their brain reacted when thinking about others and themselves. This conclusion suggests that social isolation may alter our brain's ability to map interpersonal relationships, affecting other cognitive and social processes, such as how brains perceive and interact. Individuals engaged in less social interaction during the pandemic showed decreased activation in the dmPFC and rTPJ, which is associated with the theory of mind: the ability to understand other people's thoughts and feelings. This suggests that social isolation impairs our ability to engage in complex cognitive processes, thus implying a lack of activation and functional connectivity in the SBN.

Xiong et. al (2022) found that social isolation during one's earlier years often leads to socioemotional and cognitive deficits, while social isolation later in life is associated closely with anxiety and depression. Orphaned children who spent more than six months in isolated institutions displayed many symptoms of attention-deficit hyperactivity disorder (ADHD), autism spectrum disorder (ASD), and disinhibited social engagement disorder (DSED). DSED often develops when a young child lacks affection and nurturing from caregivers, causing them to be very friendly with strangers and show overall impulsivity in social environments. EEG analysis revealed unusual patterns of brain activity in the frontal and temporal regions. Additionally, other studies have found that social isolation as a result of schizophrenia and major depressive disorder reduced functional connectivity between the left anterior dlPFC, bilateral TPJ, and precuneus regions. These regions are involved in processing salient stimuli and engaging in social cognition (Penner et. al, 2018).

The COVID-19 pandemic forced most people to rely solely on social media for constant human interaction. Bland et. al (2021) discovered that reduced contact with friends enforced by COVID-19 social isolation (CSI) predicted more accurate recognition of sad facial expressions and a more negative affective bias. The type of communication used during CSI, whether asynchronous or synchronous video calling, influenced emotion recognition, affective bias, and cooperative behavior**.** Those who opted to rely more heavily on video and phone calls than text-based communication showed more positive affective bias in emotion recognition, demonstrating that face-to-face interactions activate the emotional processing and recognition regions of the SBN. Similarly, Shimada and Hiraki (2006) studied infants' sensorimotor activation in response to watching recorded actions and engaging in live action. The infants had more activation with the live action, which suggests that digital communication may not stimulate the mirror neuron system activated when humans observe the actions of others, playing a role in emotional processing and learning. Mirror neurons have been shown to play a role in brain structures involved in empathy and TOM. Quadt et. al (2020) found that in online interactions, areas involved in TOM, such as the dmPFC and the TPJ, are still activated just as in face-to-face interactions. However, there's less activation in the dlPFC compared to real-life interactions. Additionally, the theory of mind's neural mechanisms may differ between social and non-social contexts, especially if the social feedback is salient. These findings further prove that there is a decrease in SBN activation correlated with virtual, digital, and online interactions. Finally, the study discusses the lack of depth in online relationships compared to in-person interactions and questions whether the excessive reliance on social media will satisfy our "intrinsic social needs for meaningful connections."

Social Isolation In The Elderly Population

The SBN's influence on one's ability to navigate social situations suggests that an individual may be at an increased risk for social isolation in cases of abnormal development or degradation of the SBN. Within the United States, nearly ¼ of "community-dwelling" elderly Americans experience social isolation— which poses a public health risk (National Academies of Sciences, Engineering, and Medicine, 2020). Santini et. al's 2020 study investigates the relationship between social isolation and older adults ages 57-85. The study notes that social isolation generally increases the risk of mental health disorders and statistically supports that within these older Americans, social disconnectedness increases perceived loneliness, depression, and anxiety symptoms. Subsequently, the social network structure of older adults is heavily influenced by their anxiety and depression (Santini et. al 2020). However, the physiological implications of this aren't investigated here. It is unclear whether the anxiety and depression symptoms develop as a result of decreased access to social situations or if the reduced opportunity for social connectedness degrades features in the SBN that assist in navigating social situations, later contributing to anxiety and depression. Zhang et. al's 2021 investigation expands the relationship between the SBN and the social network of individuals with schizophrenia and social anhedonia. Social anhedonia— the inability to experience pleasure from activities formerly found enjoyable– is a common symptom of many mental health disorders, including depression. Researchers found that individuals with social anhedonia, relative to healthy control groups, have higher segregation in the functional connectivity of their SBN. This means that regions of the SBN responsible for social processing work independently of one another (Zhang et. al, 2021).[4] Their condition is negatively correlated with social performance (Blanchard et al., 2011), as segregated functional connectivity presents a challenge in navigating social situations. Zhang et. al, 2021, found that social anhedonia causes individuals to report a lower sense of social support, which may also result from a decreased understanding of social relationships. This indicates a potential relationship between elderly people experiencing social isolation and abnormal SBNs. As with social anhedonia, social isolation creates significantly higher rates of clinical depression (Beutel et al., 2017). Therefore, older adults may have a segregated functional connectivity network, specifically the bilateral fusiform gyrus, the bilateral amygdala, the right inferior orbital frontal gyrus, the left precuneus, the right cerebellum, and the left cerebellum crus (Zhang et al. 2021). This may explain older adults' self-reported social isolation or maladaptive social behaviors that contribute to social isolation. Meshi et. al 2019 expand this potential relationship to maladaptive social media behaviors in older adults. However, the results are only significant when controlling for depression. The researchers were not conclusive in identifying a root cause for maladaptive social behavior in older adults. Still, one of their interpretations included no causal relationship between problematic social media use and social isolation, as there may be a casual variable unidentified by the study (Meshi et. al 2019). This casual variable could be the SBN itself; however, further research, expanding on both Meshi et al. 2019. and Zhang et al.'s 2021 findings, would be necessary for a conclusive answer.

Social Isolation and Neurodegenerative Diseases

As age advances, many older people struggle with social isolation. The progressive age-related degeneration of these brain regions involved in social and cognitive processing leads to a decline in the relative cognitive function and social abilities of elderly individuals, pushing them further into social isolation. Age-related brain degeneration often results in various functional and structural changes within regions necessary for social perception, such as the dorsomedial prefrontal cortex, orbitofrontal cortex, and lingual gyrus (Kwak 2018). As individuals age, they may experience difficulties interpreting social cues, reflecting the underlying changes in these brain regions associated with aging (Christidi 2018). As a result, these changes in social cognitive functions contribute to abnormal interpersonal behavior and increased social isolation, recognized as potential risk factors for adverse health outcomes.

This age-related social isolation can cause a harmful feedback loop for the elderly population, as studies have suggested a possible correlation between the size of one's social network and the volume of the relative brain regions that are related to social cognition, specifically dorsomedial prefrontal cortex, orbitofrontal cortex, and lingual gyrus (Kwak 2018). These studies revealed that more extensive social networks positively correlate with greater brain volume in the listed brain regions, highlighting enhanced social inference abilities. Perceived social isolation contributes to reduced overall cognitive performance, more rapid cognitive decline, and poorer executive function, confirming bias in social cognition (Morese 2022). This connection indicates the effects of social interactions on brain structure, underscoring the possible impact of one's social environment on determining neurocognitive processes. Additionally, the socio-centric measures and social brain emphasize the connection between social connectivity and neural structural integrity, conveying insights into the details behind social cognition.

The onset of neurodegenerative diseases can also accelerate social isolation. Neurodegenerative disorders, including behavioral-variant frontotemporal dementia (bvFTD) and prodromal Alzheimer's disease, often cause significant deficits in social behaviors. Individuals suffering from these neurodegenerative conditions can frequently exhibit socially inappropriate behaviors, such as a loss of empathy, impaired self-control, and difficulties in discerning social cues (Desmarais 2017). These inappropriate behaviors correspond to the neuropathological changes in the related brain regions, such as atrophy in the right temporal pole and right anterior fusiform gyrus, suggesting the connection between neuropsychiatric diseases and social dysfunction (Desmarais 2017). There is evidence supporting that the impairment in social cognitive abilities, like the perception of social information, has been noted as a symptom in patients with neurodegenerative disorders (Christidi 2018). For example, Alzheimer's disease profoundly impacts regions associated with the social brain network, such as the dorsomedial prefrontal cortex, resulting in compromised social perception and heightened social isolation. Alterations in the brain function, specifically within the default mode network, cause negative results like cognitive decline and disrupted social connectivity. The interplay between social isolation and biological mechanisms highlights its potential to exacerbate the risk of neurodegenerative disease onset, emphasizing the connectivity of social engagement and neurological well-being (Williams 2011). Abnormal interpersonal behavior listed above is a result of the affected neural regions. They can ultimately become consequences leading to social isolation, reflecting the necessity of social cognitive intervention to reduce the negative impact of such disabilities on mental health and better the ability to establish interpersonal connections.

Overall, these findings highlight the profound impact of social cognition and the SBN in establishing interpersonal relationships and social connections, illustrating the detrimental effects of social isolation and neurodegenerative diseases on social dysfunction and mental well-being.

Social Media and Salient Stimuli

Given our growing technologically-driven world, social psychology literature pushes to study similar brain activity and salient responses, focusing on social media usage. A salient stimulus is any stimulus that produces "automatic attention capture" often due to associations from previous experiences (Gaspelin and Luck 2017). With the intent of being modeled after face-to-face interactions, social media harbors a vast variety of salient stimuli in the form of social media posts, private conversations, and likes and comments (Clerke and Heerey 2022).

The presence of salient stimuli in social media shows broad implications in how one enjoys online content consumption. Research by Lauren Sherman at Temple University studies this consumption behavior of participants when they are asked to interact with a social media app, specifically the ‘Like’ feature. Brain activity is measured via an MRI scanner while a user interacts with an app. Results show that providing likes to others leads to activity in the reward system of the brain. Sherman’s study explores providing likes and its association with salience processing and executive function. The study ultimately discusses that likes, which indicate an enjoyment of content can be linked to salience on social media (Sherman et.al. 2018). The paper opens up social media content as another form of salient stimulus, as it portrays social situations and settings through an app, with “likes” representing the salient response to these situations.

A core interaction on social media also includes posting itself, which is a stimulus that has profound impacts on the reward system of the brain and perception of salience stimulus. A study conducted looks at this connection, as participants either post on social media or have a face-to-face conversation with someone. Participants subsequently complete a smile valuation task where they are shown genuine versus polite smiles. Results show that when a participant is thinking about a social media post compared to having a real conversation, they are more likely to sacrifice small financial gains to see a genuine smile. This study suggests that social media interactions enhance responses to salient stimulus and the value of salient stimulus, like a genuine smile (Clerke and Heerey 2022).

Another aspect explored in the dialogue between social media and brain activity was social media marketing and content, which is becoming an increasingly relevant and prominent aspect of the social media experience. Jing Zhang and Eun-Ju Lee dive deeper into social media marketing, specifically looking at university students, who have experience and grew up with social media. This study shows different social media marketing stimuli to participants as an fMRI records their brain activity. It was found that the reward value center of the brain, specifically in the nucleus accumbens, was further activated when aesthetic social media marketing was shown, while the informational value part of the brain, in the prefrontal cortex, was activated when news advertisements were viewed (Zhang et.al. 2022). The study connects the relevant age range of social media users to their reaction to marketing, bridging the idea of salient stimulus on social media marketing strategies and the potential exploitation and dangers of social media.

Although marketing is becoming incredibly prominent on social media networking sites, the presence and therefore consumption of content on social media has increased as well. Turel et. al conducted a study looking at if social-semantic demands increased with use of Facebook, and which anatomical structures of the brain are affected by these increases in demands. Social-semantic demands are defined as neural tasks that involve “recognizing social group members”, and interpreting their motivations. Therefore, social-semantic demands represent salient configurations and a user’s ability to identify these configurations. The study finds an increase in social-semantic and mentalizing demands with a positive association with Facebook-use. With this association also comes an increase in gray matter of regions of the social brain network including the superior temporal and left fusiform gyri (Turel et. al. 2017).

Studies conducted within the realm of social neuroscience shed light on the various salient stimuli present in online social media networking platforms and their profound impacts on the behavior and brain activity of its users.

Sociological Factors Behind Social Media Usage

This section examines the effects of online usage, including doom-scrolling (habitually, repeatedly scrolling through distressing news or social media content) and fear of missing out (FOMO for short, referring to envy or anxiety when missing out on a rewarding experience or social interaction), on the SBN.

With the rapid growth of social media before and after the COVID-19 outbreak, individuals turn to social media as a mediator for stress relief, connections, keeping up with news, and entertainment. Some uses of technology can be harmful on the SBN. For instance, H. Shakya concluded that in real world and online interactions, “the usage of Facebook was negatively associated with well-being”(H. Shakya, 2017)[1]. They discovered “likes-clicked” or “status updates (updating personal status) had a positive association with self-reported mental health struggles. N. Zhao would agree that consumption of certain types of content is a risk factor of mental health related to negative news including COVID-19. A study (N. Zhao, 2020)[2] with 512 Chinese college students (Average Age: 22.12, SD = 2.47) concludes that consuming disaster related news online has shown a negative impact on stress, making it a risk factor for depression. This negative impact can be harmful on the SBN, leading to “progressive social dysfunction” according to studies (S. Porcelli, 2018)[3]. This suggests the SBN shows several levels for social processing stimuli and social dysfunction and some forms of content found in doom scrolling can be harmful on mental health.

While online interactions are convenient and accessible, they fail to offer some perks of in-person interactions due to their limitation in conveying non-verbal cues, emotional connection, and complex social dynamics. Furthermore, studies suggest that distinct brain structures are involved in online and in-person interactions. Trials involving neuroimaging scans showed increased offline and online engagements using different SBN regions according to this study (R. Kanai, 2011)[4]. Amygdala size (structure in SBN involved in emotional responses) was positively associated with real-world network size (E. Phelps, 2004)[5] while the right entorhinal cortex (structure non-affiliated with SBN involved in encoding/episodic memory and spatial navigation) size was positively associated with online network size. This suggests that increased online connectivity may correlate with larger brain growth in distinct regions outside the SBN, training structures involving tasks such as social memory and navigation tasks rather than reading emotions and social cues.

Reports declare since the start of the COVID-19 pandemic (2020), the number of people using online media platforms like TikTok has expanded dramatically, rising from 465 million to 834 million users worldwide, an increase of over 80% (Basis Technologies, 2023)[6]. On these platforms, "Doom Scrolling" which has a negative influence on productivity and mental health. Overuse of consuming short stories such as Instagram Reels and Tiktoks, triggers an addiction comparable to drug use that occurs in the same site in the brain, the mesolimbic dopaminergic pathway (a reward system) according to studies (R. Holly, 2017)[7]. Through Facebook users (n=92, mean age = 19.55), emotionally costly Facebook content has been shown to slightly impair recovery and higher cortisol concentration. In some cases higher cortisol concentration is beneficial for regulating body conditions. However, high cortisol levels can lead to overstressing and eventually structural changes in the brain, including the hippocampus and prefrontal cortex as intense cortisol can be a risk factor for mental issues such as mental depression disorder (MDD) (Y. Wang, 2018)[8]. While doom scrolling has some initial positive entertainment, the user can find themselves in a drug-addicted state that negatively impacts the social brain network. A positive correlation between cortisol levels and strength of the connection between the left posterior cerebellum and the left medial orbitofrontal cortex (not a part of the social brain network but it plays a role in emotional regulation)[8]. This indicates that while these structures are not a part of the SBN, they have some effect on the connectivity of the SBN through social cognition and emotional regulation akin to a domino effect.

Continued online engagement could lead individuals in search of new experiences, typically of ones they see with friends or content creators leading to FOMO, inducing further altercations in the SBN. A study (M. Gerges, 2023)[9] discovered individuals who consume shorts for +5 minutes and watched sad movie shorts and climate change videos were more likely to make unrelated purchases while those who watched “neutral” content made no significant actions.

Neurochemical Factors Behind Social Media Usage

Several research studies offer compelling insights on SBN activity during interaction with various social media platforms, as well as the subsequent altering effects of social media on the SBN. One study conducted by the Association for Psychological Science shows that teenagers experienced reduced activity in brain regions that are responsible for cognitive control, such as the dorsal anterior cingulate cortex and bilateral prefrontal cortexes, while engaging in social media (Abrams, 2023). This inhibition suggests that the brain’s regulatory mechanisms are hindered upon interaction with social media.

The concept of providing and receiving ‘Likes’ online can be compared to other systems of rewards in the brain, such as those associated with monetary gain, located in the ventral tegmental area and the striatum (Sherman et al., 2018). This system has been associated with the reward circuitry of dopamine in the brain, which is located in the same place: the ventral tegmental area (Cai & Tong, 2022).

Elaborating more on the structure and functionality of the SBN, current research highlights the correlation between social network structures and brain activity. Specifically, it highlights the amygdala's role in understanding social signals. Using three social network indicators, they found that online network size, offline network size, and social support network size were positively correlated with the density of gray matter in the amygdala, as well as the right anterior temporal cortex (Han et al., 2021). Additionally, the orbitofrontal cortex, which is responsible for social behaviors such as predicting behaviors and intentionality, has also shown to be a predictor of network size (Liu 2018). These findings support the assertion that the SBN is more active because, with these correlations, these areas are more engaged in those with extensive social connections.

Researchers have also found that neurochemical and genetic factors play a significant impact in social behaviors. For instance, differences in serotonin systems can affect the density of gray matter in the amygdala, which has already been shown to be related to the SBN in previous studies (Li 2015). Differences in oxytocin and dopamine receptor genes are correlated with differences in social network structures and how people transmit both emotional and behavioral information over these networks (Han et al., 2021). The ability to support large social networks has been linked to oxytocin, the β-endorphin, and dopamine. The TT/TG genotype of the oxytocin receptor (OXTR) has also been correlated with larger social networks, identifying one specific structure that could potentially be responsible for network size in some way. On the other hand, they also identified the GG genotype of OXTR to be correlated to individuals with fewer connections in their social network. Thus, neurochemical and genetic variations can influence both the structures of brain regions associated with the SBN, such as the amygdala, on the individual's social network size.

Neuropsychiatric disorders are often characterized by disruptions in social behaviors, which suggests a potential connection between the SBN and these disorders. The delicate balance of healthy brain structure to begin with, development, and neurochemicals underscores being able to maintain healthy social interactions. Imbalances in brain co-development, when areas of the brain develop themselves and influence other areas interdependently, may lead to higher rates of internalizing problems, such as depression and anxiety (Zhao et. al, 2023). The root cause of the imbalance in co-development, though, was labeled to be excessive social media usage (Zhao et. al, 2023). But, it's important to note that for a lot of causal studies about social media, many of them feel the need to use 'excessive' or above-normal use to denote maladaptive behaviors stemming from it. There has been a motion to challenge the general claim that social media is linked to mental health disorders. For instance, one study suggests that routine use of integrated social media, without excessive emotional reliance, has been positively associated with mental health and well-being (Bekalu et. al, 2019). They have also shown the converse, that social media use, driven by emotional dependence, such as FOMO or disappointment, is negatively associated with health and well-being. Both studies show the need for further research to be studied on the relationship between social media and mental health to make more general claims about, not just limiting itself to excessive use or self-moderated use but to all uses.

Discussion

Our study aimed to explore the function and purpose of the Social Brain Network (SBN) in the brain. To do this, we examined the SBN's activation in both social and non-social contexts. The replication of Lugrin et al. (2023)'s study confirmed the significant role of the SBN in processing specifically salient stimuli, providing a solid foundation for our extension research. Our extension research delved into the variations in SBN activation during different kinds of social engagement, comparing the salient stimuli present in social media interactions with the salient stimuli in face-to-face encounters. We found that social isolation, particularly in case studies such as isolation in the COVID-19 pandemic and isolation among elderly populations, led to decreased activation in key areas of the SBN, impacting cognitive and social processes. Additionally, our analysis of social media's influence on the SBN revealed that online interactions, while stimulating certain brain regions in the SBN, does not create the same kinds of SBN activation patterns as face-to-face interactions and therefore might not fully satisfy the intrinsic social needs for meaningful connections.

Future research in this field could aim to explore the long-term effects of social media use on the SBN, considering the increasing prevalence of online interactions in modern society. Additionally, studies should investigate the potential reversibility of SBN alterations caused by social isolation, particularly in the context of post-pandemic recovery and reintegration into social environments.

In conclusion, our study highlights the intricate relationship between the SBN and social interactions, both in physical and digital realms. Understanding the neural underpinnings of social behavior and online engagement can inform interventions and policies aimed at promoting mental health and social well-being in an increasingly connected world.

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