The Neural Basis of Social Concept Representation and Integration

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Abstract

The representation and integration of social concepts constitute a crucial foundation for human understanding and reasoning about social information, and the neural underpinnings of this issue are emerging as a novel research focus. Existing evidence from brain imaging and lesion studies has relatively consistently indicated that social concept representation primarily relies on a brain network composed of bilateral anterior temporal lobes, temporoparietal junction, dorsomedial prefrontal cortex, posterior cingulate cortex, and adjacent precuneus. Recent functional neuroimaging studies suggest that, in addition to supporting social concept representation, the aforementioned brain regions also participate in different levels of social concept integration. Future research can continue to deepen and expand along the lines of sub-dimensions of social concept representation, sub-components of social concept processing, and behavioral effects of social concept processing.

Full Text

Neural Basis of Social Concept Representation and Integration

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Abstract: The representation and integration of social concepts form the foundation for how people comprehend and think about social information, and their neural underpinnings are gradually emerging as a new research frontier. Existing neuroimaging and lesion studies have convergently suggested that social concept representation primarily relies on a brain network comprising the bilateral anterior temporal lobes, temporoparietal junction, dorsomedial prefrontal cortex, posterior cingulate gyrus, and adjacent precuneus. Recent functional neuroimaging studies further indicate that these brain regions, in addition to supporting social concept representation, are also differentially involved in social concept integration across various levels. Future research should continue to deepen and expand investigations into the sub-dimensions of social concept representation, the sub-components of social concept processing, and the behavioral impacts of social concept processing.

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People acquire vast amounts of social information through language every day. Research has found that approximately two-thirds of daily conversations revolve around social topics (Dunbar et al., 1997). Despite the complex cognitive processes involved, acquiring social information through language is typically efficient and effortless—in fact, people even derive pleasure from it, as evidenced by the proliferation of entertainment programs centered on social discourse. How does the human brain efficiently and effortlessly comprehend the social information conveyed through language? To address this question, we must first understand the foundation that supports social information processing: the representation and integration of social concepts.

Concepts constitute the psychological representation of word meanings and enable people to categorize things (Medin & Smith, 1984). It is generally believed that when the brain constructs complex meaning representations (e.g., the semantic representation of a sentence), it first retrieves concept representations from long-term memory into working memory and then integrates multiple concepts. Although researchers have long been interested in concept representation and integration, they did not initially treat social concept representation and integration as a distinct research problem. It was not until the early twenty-first century that two important phenomena prompted researchers to launch specialized investigations into this topic. The first phenomenon is the domain-specificity of brain function for social information. Studies have found that multiple cognitive systems in the brain (such as vision, audition, attention, reasoning, and learning) contain brain regions that are selectively sensitive to specific social stimuli (e.g., faces, bodies, voices, personality traits, motivations, mental states). This phenomenon is termed social domain specificity (Molapour et al., 2021; Spunt & Adolphs, 2017). Some researchers argue that social information processing has shaped the brain during species evolution and individual development, forming a "social brain" system that gives rise to social domain specificity (Dunbar & Shultz, 2007; Sallet et al., 2011). The second phenomenon is the distributed representation of concepts in the brain. Extensive evidence from brain lesion and functional neuroimaging studies suggests that concepts (or semantic information) are represented in a distributed manner in the brain, with neural representations of different concept types (e.g., shape, color, sound, action, emotion) being anatomically separable (Binder et al., 2016; Huth et al., 2016; Mahon & Caramazza, 2009). Based on these two lines of evidence, some researchers have hypothesized that social concept representation and processing may involve specialized neural substrates (Caramazza & Mahon, 2006; Mitchell et al., 2002; Zahn et al., 2007; Lin et al., 2015), thereby initiating research on the neural basis of social concept representation and integration.

1. Definition and Scope of Social Concepts

The definition and research scope of social concepts have undergone dynamic evolution. In social psychology, research on specific concept types such as personality has a long history (Allport, 1937). However, it has only been about two decades since researchers began to treat more general social concepts as objects of study and explore whether their representation and processing have unique neural underpinnings.

Mitchell et al. (2002) conducted a pioneering functional magnetic resonance imaging (fMRI) study investigating the neural representation of person knowledge. In this study, Mitchell and colleagues defined person knowledge as "general knowledge about the implicit, unobservable attributes of social agents" and revealed its neural correlates by comparing brain activation during person attribute judgment tasks versus object attribute judgment tasks. The "person knowledge" proposed by Mitchell et al. can be considered an early definition of social concepts.

Subsequently, more researchers began to study social knowledge from the perspective of concept representation. However, although these studies had shifted their focus to general social knowledge, the experimental stimuli they employed did not extend beyond classic concept types in social psychology, such as personality concepts (Zahn et al., 2007) and mental state concepts (Mitchell et al., 2005).

As research on social concepts gradually developed, researchers' definitions and research scope changed. In terms of definition, recent studies exhibit two characteristics. First, most recent research defines social concepts from the perspective of semantic dimensions rather than semantic categories (Arioli et al., 2021; Binder et al., 2016; Catricalà et al., 2020; Diveica et al., 2022; Lin et al., 2015, 2019, 2020; Lin, Wang, et al., 2018; Troche et al., 2017; Vargas & Just, 2020; Villani et al., 2019; Wang et al., 2019, 2023; Zahn et al., 2007; Zhang et al., 2021, 2022). The notion of semantic dimensions originates from the multidimensional semantic space hypothesis (Osgood, 1952), which posits that concepts are represented along multiple semantic dimensions, with each concept quantifiable as a point in this multidimensional space. In recent years, quantitative semantic models based on this hypothesis have achieved great success in computational linguistics and cognitive neuroscience (Binder et al., 2016; Fu et al., 2023; Huth et al., 2016; Kumar, 2021; Wang et al., 2020). Consequently, the dimensional approach is gradually becoming mainstream in current concept (semantic) research. From this perspective, recent studies generally assume that there exists a continuous semantic dimension in semantic space representing the degree of sociality, and those concepts with higher sociality are considered social concepts, or high-sociality concepts. Another reason researchers favor the dimensional approach is that word meanings often change with context. For example, while the word "eating" is not necessarily linked to social interaction, in contexts such as hosting guests, group meals, or wedding banquets, "eating" becomes a social behavior. Therefore, when considering all possible contexts for a word or concept, people's evaluations of different words' or concepts' sociality tend to follow a continuous rather than categorical distribution. Second, although some early social concept research emphasized the uniqueness of person knowledge, recent studies universally regard the degree to which a concept involves interpersonal interaction as the core criterion for measuring its sociality (Arioli et al., 2021; Binder et al., 2016; Catricalà et al., 2020; Diveica et al., 2022; Harpaintner et al., 2018; Lin et al., 2015, 2019, 2020; Lin, Wang, et al., 2018; Troche et al., 2017; Vargas & Just, 2020; Wang et al., 2019, 2023; Zhang et al., 2021, 2022). Empirically, Lin et al. (2015) provided crucial evidence comparing the neural validity of these two definitional approaches. Using fMRI, this study compared brain activation during comprehension of social action verbs (human action verbs frequently involving interpersonal interaction, e.g., "pickpocketing"), private action verbs (human action verbs rarely or never involving interpersonal interaction, e.g., "brushing teeth"), and non-human verbs (verbs describing physical, chemical, or biological phenomena, e.g., "melting"). The results revealed that social action verbs elicited significantly stronger activation than the other two verb categories in brain regions including the bilateral anterior temporal lobes, temporoparietal junction, dorsomedial prefrontal cortex, posterior cingulate gyrus, and adjacent precuneus. Moreover, across most of these regions, activation strength decreased significantly from social action verbs to private action verbs to non-human verbs. These findings suggest that the brain's sensitivity to social concepts is influenced not only by person knowledge but more importantly by the degree of association between concepts and interpersonal interaction.

Regarding research scope, recent studies have expanded the domain from classic concept types in social psychology, such as personality and mental states, to more general concept types like objects and actions, enabling direct connections with classic concept and language research. In this regard, a series of studies by Chinese scholars Lin et al. (2015, 2019), Lin, Wang et al. (2018), and Wang et al. (2019) are particularly representative. These fMRI studies examined differences in neural activity elicited by high-sociality words (e.g., "money," "pickpocketing," "trust") versus low-sociality words (e.g., "battery," "brushing teeth," "inferring") across the most common concept categories in previous research: object concepts, action concepts, and abstract concepts. The results showed that neural activity in specific brain regions was sensitive to the sociality of concepts across all these categories, exhibiting stronger activation for high-sociality words. These findings provide clear neural evidence for the universal applicability of the social semantic dimension across different concept types and have substantially broadened the actual research scope of social concepts. Notably, although many studies have emphasized the importance of social semantic dimensions primarily in abstract concept representation (王晓莎, 毕彦超, 2019; Pexman et al., 2022), the aforementioned studies strongly suggest that even for the most concrete concept categories—object concepts and action concepts—sociality is a valid and important semantic dimension.

In summary, early research typically defined social concepts as the sum of concept categories describing internal person knowledge (e.g., personality, mental states) and investigated them by contrasting social category concepts with other categories (e.g., Mitchell et al., 2002; Zahn et al., 2007). Recent research, in contrast, more often defines social concepts from a semantic dimension perspective, manipulating sociality levels within the same concept category (e.g., Lin et al., 2015, 2019; Wang et al., 2019) to examine the representation and integration of social knowledge contained in each concept category individually. This shift in definitional approach represents more than a mere methodological change—it has led researchers to recognize and demonstrate that when thinking about concepts originally considered non-social categories (such as inanimate artifacts, Lin et al., 2019), the brain still engages in social information processing, and corresponding neural activity can be observed in relevant brain regions. Therefore, defining social concepts based on semantic dimensions can more comprehensively reflect the distribution of social information in the conceptual system. It must be emphasized that despite these changes in definitional approach and research scope, the fundamental reasons for researchers' interest in social concepts remain unchanged. This research has consistently stemmed from attention to two aspects of social concepts' special status relative to other concepts. First, social concepts are the cornerstone for understanding and navigating complex social relationships (Pexman et al., 2022). Therefore, a fundamental understanding of the cognitive mechanisms underlying human social behavior necessarily requires deep knowledge of how the brain represents and integrates social concepts. Second, the representation and processing of social concepts likely involve specialized neural substrates, which is consistent with both the social brain hypothesis and the distributed representation hypothesis (Binder et al., 2016; Binney & Ramsey, 2020) and is receiving increasing empirical support. Below, we review evidence for these claims from the perspectives of social concept representation and integration.

2. Neural Basis of Social Concept Representation

Current research on the neural basis of social concept representation primarily addresses two questions: First, which brain regions and networks are mainly involved in social concept representation? Second, are the neural representations of social concepts and other concept types separable? From a methodological perspective, researchers typically employ word comprehension tasks to elicit activation of social concept representations in the brain, with judging semantic relatedness or similarity between words being the most commonly used task type (Lin et al., 2015, 2019; Lin, Wang, et al., 2018; Pobric et al., 2016; Wang et al., 2019, 2021; Zahn et al., 2007, 2009).

Regarding the brain regions and networks involved in social concept representation, evidence comes from both functional neuroimaging and lesion studies. Functional neuroimaging evidence is entirely derived from fMRI studies, most of which compare neural activation intensity elicited by high-sociality versus low-sociality concepts across different brain regions. The underlying assumption is that brain regions involved in social concept representation should show higher activation for high-sociality concepts. The studies by Lin et al. (2015, 2019), Lin, Wang et al. (2018), and Wang et al. (2019) introduced above are typical examples of this approach. To date, this line of evidence has reached considerable scale, with two targeted meta-analyses (Arioli et al., 2021; Zhang et al., 2021) indicating that the bilateral anterior temporal lobes, temporoparietal junction, dorsomedial prefrontal cortex, posterior cingulate gyrus, and adjacent precuneus (see Figure 1 [Figure 1: see original paper]) consistently show higher activation for high-sociality than low-sociality concepts, suggesting their involvement in social concept processing. Building on these findings, researchers have further examined the network properties of these brain regions through functional connectivity analyses. These studies reveal that these regions all lie within the brain's default mode network and exhibit very strong functional connectivity among themselves, suggesting that they are functionally tightly linked and constitute a brain network supporting social semantic processing (Lin et al., 2020; Lin, Wang, et al., 2018).

In addition to activation intensity studies, a small number of studies have used multivoxel pattern analysis (MVPA) to investigate the neural correlates of social concept representation (Tamir et al., 2016; Thornton & Mitchell, 2018; Van Overwalle et al., 2016). These studies employ relative activation patterns across neighboring brain regions as dependent measures. For example, Tamir et al. (2016) obtained whole-brain activation patterns for 60 mental state concepts and used a searchlight approach to MVPA to examine their influencing factors across the entire brain. The results showed that similarity of mental state concepts on a composite dimension of sociality and arousal could predict the similarity of multivoxel activation patterns in specific brain regions, suggesting that these regions subserve the representation of social-emotional knowledge. Although such studies are rare, the brain regions they identify are largely consistent with those found in activation intensity studies, providing converging evidence for these regions' involvement in social concept representation (Tamir et al., 2016; Thornton & Mitchell, 2018; Van Overwalle et al., 2016).

Lesion study evidence comes from brain-damaged patients and transcranial magnetic stimulation (TMS) studies in healthy participants. The advantage of this evidence lies in its ability to test causal relationships between brain region function and behavioral performance—that is, whether damage to or interference with specific brain regions leads to difficulties in social concept processing. However, limited by lesion distribution in patients or the number of stimulation targets, such studies can typically only examine the function of a subset of brain regions. Existing studies have suggested that damage to the right anterior temporal lobe (Catricalà et al., 2020; Pobric et al., 2016; Younes et al., 2022; Zahn et al., 2009, 2017), left parietal lobe (Wang et al., 2021), right intraparietal sulcus (Catricalà et al., 2020), left anterior temporal lobe, dorsomedial prefrontal cortex, and right orbitofrontal cortex (Zahn et al., 2009) may impair social concept processing. The main findings of these studies are summarized in Table 1 .

Regarding whether neural representations of social concepts are separable from those of other concept types, current research provides evidence at two levels: single dissociation and double dissociation. The first level is single dissociation evidence, which indicates that social concept representation involves additional neural activity or requires additional neural structures compared to other concepts. Most studies introduced above included non-social concepts (in category-based definition studies, e.g., Mitchell et al., 2002; Pobric et al., 2016; Zahn et al., 2007, 2009, 2017) or low-sociality concepts (in dimension-based definition studies, e.g., Lin et al., 2015, 2019, 2020; Lin, Wang, et al., 2018; Wang et al., 2019, 2021) as control conditions, and excluded general conceptual processing effects through contrasts between experimental and control conditions in data analysis. Readers may refer to Table 2 in Zhang et al. (2021) for a summary of neuroimaging studies and Table 1 in this article for a summary of lesion studies regarding the specific experimental and control conditions employed and main findings. These results at least constitute single dissociation evidence, reflecting neural activity or structures specific to social concepts relative to other concepts.

The second level is double dissociation evidence, which indicates that social concept representation and other concept representation involve different neural activities or require different neural structures. Double dissociation evidence is more difficult to obtain than single dissociation evidence and is less susceptible to confounding by a single variable (such as task difficulty), and is therefore considered stronger evidence. Among the studies mentioned above, some have reported double dissociation evidence. In functional neuroimaging research, Mitchell et al. (2002) found that person knowledge and object knowledge elicited stronger neural activity in two distinct sets of brain regions, suggesting separate neural representations for the two types of knowledge. Lin, Wang et al. (2018) found that different brain regions were sensitive to the sociality versus visual imagery of verbs, suggesting that social and visual dimensions of lexical conceptual knowledge are neurally separable. Additionally, studies by Wang et al. (2019) and Peer et al. (2015) also suggested that social concepts are neurally separable from emotional, spatial, and temporal concepts in terms of brain region distribution. In lesion research, Zahn et al. (2009) reported a double dissociation between social concept impairment and animal function concept impairment, with different patients showing significantly more severe comprehension deficits on social concept versus animal function concept tasks. Wang et al. (2021) reported a double dissociation between high-sociality abstract concept impairment and low-sociality abstract concept impairment, with different patients showing significantly more severe deficits on high-sociality versus low-sociality abstract concept comprehension tasks.

These two levels of evidence strongly suggest the special status of social concept representation in neural mechanisms. However, it is worth noting that some studies have also reported overlap between social concepts and other concepts in neural correlates. Functional neuroimaging studies by Lin, Wang et al. (2018) and Peer et al. (2015) both found that although neural representations of social concepts and other concept types are largely separable, there are also small overlapping regions, mainly in the bilateral temporoparietal junction and precuneus. These overlapping regions are thought to be semantic hubs that link and bind different types of conceptual knowledge (Lin, Wang, et al., 2018). Lesion studies have found that damage to the left anterior temporal lobe and right intraparietal sulcus simultaneously impairs processing of social concepts and other concepts (such as quantity concepts and animal function concepts) (Catricalà et al., 2020; Pobric et al., 2016). However, functional neuroimaging data suggest that fine functional segregation for different concept types exists between adjacent regions within these brain areas (Lin, Wang, et al., 2018; Wang et al., 2019; Peer et al., 2015). Therefore, simultaneous impairment of social and other concepts following damage to these regions could result from two possibilities: either the brain regions supporting different concept types overlap, or the effects of brain lesions or TMS are spatially diffuse and simultaneously affect adjacent but functionally distinct regions.

Another important issue is that, without proper control, the social semantic dimension can easily be confounded with other semantic dimensions, requiring careful interpretation of experimental results. Fortunately, these confounds have been controlled in at least some studies, which have obtained findings consistent with other research even after controlling for confounding variables. For example, Zahn et al. (2007) contrasted personality concepts with animal function concepts, confounding two definitions of social concepts: "person-specific concepts" and "concepts related to social relationships and interactions." As mentioned earlier, this definitional confound was controlled in Lin et al. (2015). Similarly, Tamir et al. (2016) conducted principal component analysis on multiple semantic dimensions, resulting in a composite dimension of sociality and arousal. Consequently, their results likely confounded the neural correlates of social concepts with those of emotional concepts. In contrast, Wang et al. (2019) and Arioli et al. (2021) specifically distinguished between social and emotional semantic neural correlates, avoiding such confounds while obtaining findings consistent with previous research.

In summary, functional neuroimaging and lesion evidence convergently suggest that social concept representation relies on a brain network comprising the bilateral anterior temporal lobes, temporoparietal junction, dorsomedial prefrontal cortex, posterior cingulate gyrus, and adjacent precuneus. This brain network has the following characteristics: First, both activation levels and multivoxel activation patterns within network regions reflect differences between social and non-social concept processing. Second, most regions within the network function specifically for social concept processing, with only a small number of regions also being sensitive to other concept types. Third, brain regions within the network exhibit strong functional connectivity. Fourth, damage to local regions within the network impairs social concept processing.

It is worth noting that although the view that "social concept representation relies on a specialized brain network" has been proposed in studies by Lin, Wang et al. (2018), Lin et al. (2020), and Zhang et al. (2021, 2022), it has not been comprehensively demonstrated with multi-perspective evidence. The dominant view in the field remains the assertion by Zahn et al. (2007) in their classic fMRI study that "social concepts are represented in the superior anterior temporal cortex." Regarding the sensitivity of brain regions beyond the anterior temporal lobe to social concepts, most existing studies either do not discuss it or infer that it may reflect higher-level social cognitive processing (such as theory of mind) rather than social concept representation itself (Arioli et al., 2021; Binney & Ramsey, 2020; Pexman et al., 2022). However, these subsequent studies have not provided new evidence, merely following Zahn et al. (2007). Nevertheless, Zahn et al.'s (2007) findings cannot negate the social concept representation function of brain regions beyond the anterior temporal lobe. Theoretically, there is no reason to assume that all brain regions involved in social concept representation must exhibit behavioral descriptiveness effects and semantic relatedness effects. Methodologically, we should not make inferences based on statistically non-significant results. Through the comprehensive review of functional neuroimaging and lesion evidence presented above, this article finds that the importance of multiple brain regions beyond the anterior temporal lobe (temporoparietal junction and midline brain structures) for social concept representation is supported by multi-perspective evidence (activation intensity, multivoxel activation patterns, behavioral effects of lesions). Particularly noteworthy is that MVPA studies have consistently found that these brain regions exhibit social concept decoding effects (Tamir et al., 2016; Thornton & Mitchell, 2018; Van Overwalle et al., 2016)—based on activation in these regions, researchers can even effectively decode specific personality dimension information embedded in sentence semantics (Thornton & Mitchell, 2018; Van Overwalle et al., 2016). This evidence more directly reflects the neural basis of social concept representation than the behavioral descriptiveness and semantic relatedness effects examined by Zahn et al. (2007). Therefore, we argue that current evidence more strongly supports the view that social concept representation relies on a specialized brain network.

3. Neural Basis of Social Concept Integration

Concept integration involves multiple levels. For language comprehension, integrating words into phrases, phrases into sentences, and sentences into discourse requires concept integration at different levels. Research on the general neural basis of concept integration has a long history, identifying brain regions such as the left inferior frontal gyrus as key areas involved in general conceptual (semantic) integration (朱祖德 et al., 2011). However, research on concept representation has found that different types of conceptual information (e.g., visual, motor, social, emotional, temporal, spatial) are distributed across different brain regions and neural networks (Binder et al., 2016; Wang et al., 2023), a distributed representational approach that has not received sufficient attention in traditional concept integration research.

Concept representation and integration are closely linked cognitive functions, and according to some recently popular theoretical models (such as the process memory model, Hasson et al., 2015), information representation and processing often depend on the same brain regions. It follows that concept integration may also occur within distributed conceptual representation systems or in brain regions closely connected to them—that is, the integration of different types of conceptual information likely relies on different brain regions and neural networks. To date, few studies have examined the neural correlates of specific types of concept integration. Such studies follow the basic research paradigm of general conceptual (semantic) integration but manipulate the types of conceptual information contained in stimuli to compare the neural correlates of different concept integration types. Preliminary evidence suggests that social concept integration has unique neural correlates compared to non-social concept integration, with brain region distributions highly similar to those identified in social concept representation research.

Two fMRI studies have examined the neural basis of phrase-level social concept integration. Lin et al. (2020) investigated phrase-level social concept integration by manipulating the sociality and plausibility of phrases, using brain region activation levels as their measure. The study found that different brain regions were sensitive to phrase sociality versus plausibility, suggesting these regions were respectively involved in social semantic processing and phrase semantic integration. However, Lin and colleagues did not find significant interactions between the two factors in any brain region, thus failing to identify any region selectively involved in phrase-level social concept integration. Yang and Bi (2022) used five stimulus types to examine phrase-level social concept integration: social phrases (e.g., "hug mother"), action phrases (e.g., "fold tissue"), mismatch phrases (e.g., "fold patient"), social words (e.g., "hug"), and action words (e.g., "fold"). This study used three measures to reflect social concept integration: differences in activation intensity between social phrases and other conditions, differences in representational similarity analysis results between social phrases and other conditions (action phrases, social words, action words), and differences in additive and multiplicative relationships between social phrases and their constituent words versus action phrases and their constituent words. The results showed that in the inferior occipital gyrus and adjacent inferior temporal gyrus, all three measures indicated social phrase integration effects. Yang and Bi proposed that although this region's involvement was somewhat unexpected, it is adjacent to the occipital face area and has been found to participate in some higher-level social cognitive tasks, suggesting it may be involved in at least some types of social concept integration. Additionally, the bilateral anterior temporal lobes also showed social concept integration effects in representational similarity analyses.

Two other studies have examined the neural basis of sentence- and discourse-level social concept integration. Zhang et al. (2021) simultaneously investigated the neural basis of sentence- and discourse-level social concept integration in an fMRI experiment. This experiment manipulated both linguistic level (discourse, sentence, word) and semantic sociality (high, low) and used two independent measures to reflect social concept integration: differences in semantic sociality effects across linguistic levels, and the explanatory power of sociality ratings at higher linguistic levels on elicited activation after controlling for contributions from lower-level linguistic units in hierarchical regression. Both measures indicated that the classic brain regions involved in social concept processing—the bilateral anterior temporal lobes, temporoparietal junction, dorsomedial prefrontal cortex, posterior cingulate gyrus, and adjacent precuneus—were involved in sentence-level social concept integration. Furthermore, hierarchical regression results suggested that the bilateral temporoparietal junction may be involved in discourse-level social concept integration. Lin, Yang et al. (2018) examined discourse-level social concept integration by comparing differences in brain activation elicited by opening versus closing sentences in social versus non-social discourses. The rationale behind this comparison was that closing sentences require integration of preceding context and thus involve more semantic integration processing. The results showed that the bilateral temporoparietal junction and middle temporal gyrus exhibited stronger social concept integration effects in social discourses than in non-social discourses, and that the semantic integration effects in the right temporoparietal junction and middle temporal gyrus were specific to social discourse processing. Additionally, Kaplan et al. (2017) reported findings similar to Lin et al., showing that social semantic effects in discourse closing sections were stronger than in opening sections in the bilateral temporoparietal junction and medial frontal and parietal regions.

An important question is whether findings from social concept integration research can be analogously extended to other types of concept integration research. To date, insufficient evidence exists to clearly reveal the neural basis of non-social concept integration (e.g., visual, motor). On one hand, direct investigations of this issue in the literature are very rare and have reported null results (Price et al., 2015; Yang & Bi, 2022). On the other hand, some discourse processing studies have reported distributed representation and processing of different discourse information types in the brain (Speer et al., 2009; Tamir et al., 2016), but these studies did not control for lexical-level concept activation effects and therefore cannot demonstrate that the neural correlates of non-social concept integration are distributed. Thus, the neural basis of non-social concept integration remains to be further explored.

In summary, comparing results from social concept representation and social concept integration studies reveals that the main brain regions identified in social concept representation research are involved in one or more levels of social concept integration. Phrase-level social concept integration may involve the anterior temporal lobes, discourse-level integration primarily involves the temporoparietal junction, while sentence-level integration may involve all these brain regions. Beyond these regions, the bilateral inferior occipital gyrus and inferior temporal gyrus may be involved in phrase-level social concept integration, and the bilateral middle temporal gyrus may be involved in discourse-level integration. However, it should be noted that current research on social concept integration is limited in number, relies solely on fMRI technology, and has only found single dissociation evidence (i.e., additional neural signals elicited by social semantic integration). Therefore, conclusions from this line of research await further verification.

4. Future Directions

Research on social concept representation and integration is burgeoning and warrants exploration in many aspects. Among these, we believe the following five questions are particularly prominent for the next stage of research.

First, sub-dimensions of social concept representation. Social concepts encompass rich information types. From the semantic dimension perspective, many current neurobiological studies of social concept representation only make coarse distinctions between social and non-social concepts, yet more fine-grained social semantic sub-dimensions must exist that can differentiate social concepts with different content more precisely. This has already been extensively demonstrated in specific social concept domains such as personality (Thornton & Mitchell, 2018). Future comprehensive and in-depth exploration of social concept dimensions will inevitably unfold.

Second, sub-components of social concept processing. Concept processing involves not only integration but also cognitive control, working memory, reasoning, and other cognitive components. From the social brain hypothesis perspective, domain-specific phenomena may exist in all these components. For some of these components, researchers have already proposed such hypotheses (e.g., social control; for a review see Binney & Ramsey, 2020). Beyond representation and integration, what other specialized sub-components does social concept processing include? This is another question that future social concept processing research must answer.

Third, fine-grained division of labor within the brain network supporting social concept processing. Through recent research, we have learned that social concept representation and integration depend on multiple brain regions that are tightly functionally connected, forming a brain network. However, we still lack sufficient understanding of the fine-grained division of labor among regions within this network. Research on social semantic integration has preliminarily revealed functional differences among these brain regions, but such evidence remains scarce and highly inferential, requiring further in-depth examination and exploration.

Fourth, clarifying whether the general neural basis of language and semantic processing revealed by previous functional neuroimaging studies has been confounded by social semantic processing effects. A large proportion of natural speech revolves around social topics (Dunbar et al., 1997), so natural language stimuli typically contain rich social concept information, and the neural activation elicited by these social concepts may be confounded with activation elicited by general language or semantic processing. Consistent with this speculation, the language processing brain network (Malik-Moraleda et al., 2022) and general semantic representation brain network (Binder et al., 2009) identified in previous literature both contain numerous brain regions sensitive to social concepts. Based on existing literature (e.g., Huth et al., 2016; Lin et al., 2020; Lin, Wang, et al., 2018), we already know that many brain regions in so-called general language or semantic networks are not equally sensitive to all types of conceptual information, and these networks contain brain regions relatively sensitive to various concept types (e.g., social concepts, visual concepts). Have previous functional neuroimaging studies of language processing and general semantic representation been confounded by social semantic processing effects? Are some brain regions in these networks only sensitive to social concept processing? This is an urgent question requiring clarification.

Fifth, behavioral impacts of social concept processing. Differences in representation and processing mechanisms across concept types may lead to behavioral differences in tasks. For example, words with high imageability and high emotionality show relatively shorter reaction times in lexical decision tasks (Balota et al., 2004; Kousta et al., 2011). Social concept representation and integration have relatively unique neural mechanisms—what are their behavioral impacts? Research in this area has just begun (Diveica et al., 2022; Xia et al., 2023). Future integration of behavioral and neural evidence will better facilitate the revelation of the cognitive and neural mechanisms underlying social concept representation and integration.

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Note: Figure translations are in progress. See original paper for figures.