Social Cognition: Concepts and Neural Bases.

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The growing interest in the mechanisms determining the social functioning of human beings has raised the challenge of obtaining an accurate concept of social cognition and its related mechanisms, because several neurologic and psychiatric diseases exhibit related impairments since earliest stages. Social Cognition is defined as the integration of mental processes allowing the interaction among subjects and it includes phenomena as Social Perception, Theory of Mind and Empathy (or the affective response to the mental state of other people). In this article, as the primary aim, we expose the main concepts and neural basis in order to make easier the first approach for those looking for an application in the research with clinical populations.

Keywords: Social Cognition, Theory of Mind, Social Perception, Empathy, Socialization, Cognition.

Introduction

Different cognitive abilities have been associated with the successful development of social interaction. The existence of mechanisms to select environmental elements, which require certain reactions from the subjects involved, explains this phenomenon [(1)]. Both notions recognize the existence of cognitive and behavioral components in social interactions.

Even considering that social cognition and social behavior have been present in relevant events throughout the history of neurology, as in the case of Phineas Gage, its importance as an independent source of cognitive deterioration has been relegated to comparatively lower levels of attention. The importance of the clinical valuation of social cognition has been recently recognized through its inclusion in the Diagnostic and Statistical Manual of Mental Disorders (DSM-V) where this domain is considered as one of the six fundamental neurocognitive domains[(2,3)]. This emphasis emerges from experience in widely studied pathologies. For example, patients with schizophrenia are frequently excluded from relevant social activities, such as work

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and interactions with family and friends[4]. The latter has been attributed to an impediment in the identification of the inconvenience of one's own actions in a determined social environment or a failure in the capacity to adequately attribute intentionality to interacting subjects. These abilities are directly related to the atrophy of grey matter, which corresponds to a phenomenon of the pathological anatomy of the disease itself[5-9]. This example provides the initial idea of the interaction and dependency between external and internal cognitive processes.

On the other hand, the compromise of social performance responds to a central event in the pathogeny and clinical manifestation of the autism disorder spectrum. Its definition considers the presence of a persistent deficit in social interaction, emotional communication, and reciprocity, generating significant difficulties in their social and professional performance[2]. The evidence available suggests that there is a decoupling between different brain regions during its development[10]. This would explain why patients show lower performance in empathy tests[11], a relevant clinical element closely related with the functional compromise of the neuronal networks involved[12]. Likewise, specific clinical cases show an identified pattern of compromised social cognition related to structural and functional changes belonging to each illness. This notion has been reinforced by the identification of neuronal networks that have been systemically involved in the functioning of theoretical subsystems of social cognition[4].

The examples previously discussed facilitate a more educational vision of the components of social interaction. Firstly, we distinguish that behavioral and cognitive phenomena participate in this domain. **Figure 1** shows a schematic representation of social cognition, despite its complex and dynamic nature being widely accepted. In this article, due to the feasibility of measurement and given the importance of its compromise in the functioning of the individuals at the societal level, we focus on the cognitive components of social cognition , such as the Theory of Mind, Social Perception and Empathy.

The objective of the present article is to introduce the concept of social cognition and its subsystems, as well as review evidence related to its neural correlatives.

Social Cognition

We understand social cognition as the integration of processes that allow the interaction of subjects from the same species. It corresponds to an essential function for the survival of the subjects and the species. It depends on the exchange of social signs that allow them to obtain information about the other subjects involved, and to learn about their surroundings based on those signals. Starting from basic phenomena such as the attribution of intention, social cognition allows for the existence of a common reality among people [13,14].

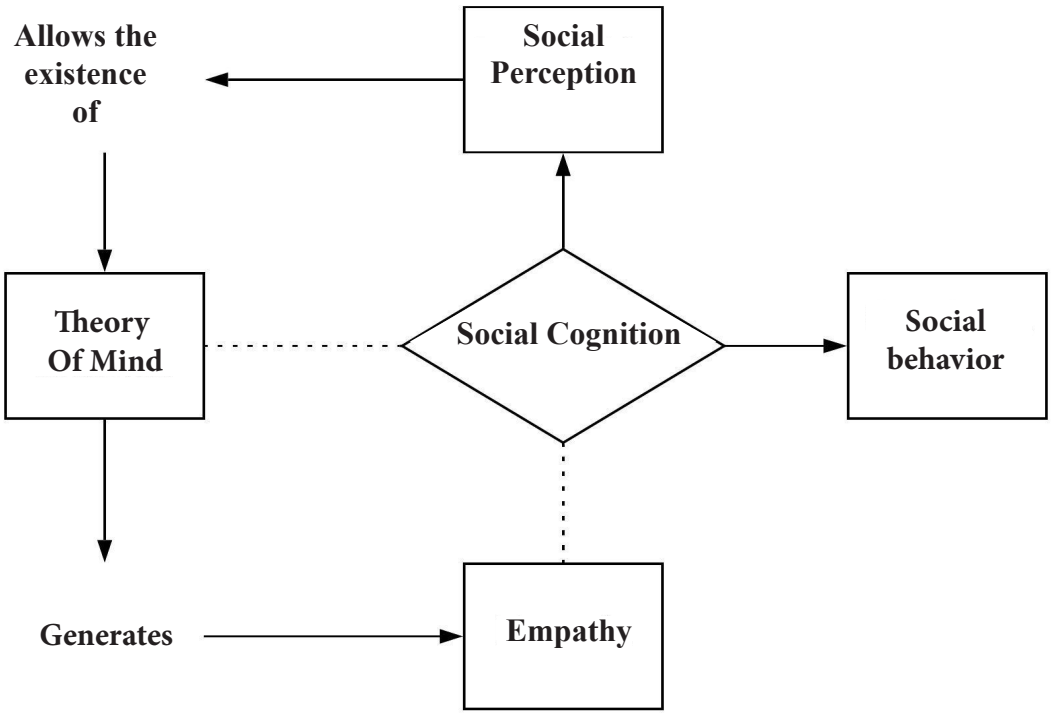
For current models, the human brain operates as a system of probabilistic inference, hierarchically organized to constantly anticipate the potential stimulus it will receive and infer their possible underlying causes [15]. In this vein, the principal product of cognitive cognition would be the generation of predictions (top-down) with the goal of diminishing the difference between predicted and realized entries[16]. For example, a correct interpretation of a facial expression would lead to the correct prediction of the response from other subjects and an adequate preparation for the correct response.

In disease models, social cognition tends to fail, appearing in a clinically evident form disturbances in the following components: Deterioration of the Theory of Mind or mentalization, diminished empathy, or poor social perception[4]. The following paragraphs analyze these concepts.

Theory of Mind

For a successful socialization, we need to recognize the experiences and intentions of other people as an independent factor. This ability to represent the psychological perspective of other subjects is known as mentalization, and requires subjects to theorize intimately about the thoughts of others. This phenomenon is known as the Theory of Mind (ToM)[17].

Figure 1. Social Cognition, as a global term, unifies the activity of internally- and externally- directed processes. There are relationships of dependence and complementarity in between the subdomains.



This concept has been frequently defined as the capacity to infer the mental states of individuals, their beliefs, or their intentions, [4, 18] and has been measured under different experimental approaches, such as those based in figures, short stories, and animations. This domain must not be considered as a monolithic ability used in specific occasions, as the mere presence of another subject in the scene has been shown to unleash neural processes to compute their possible thoughts or intentions[19]. This characterization also recognizes the existence of primitive levels of inter-subjectivity that operate even at the perceptual or attentional level[20].

Generally, ToM tests evaluate this function from two different angles: "Perspective Taking", which requires an inference about the mental state of another subject, or "Decoding", which is the mental state that must be identified as an expression, for example, of the eyes[21].

From a neuro-anatomical perspective, there are tests that support the existence of network underlying these functions. The mid pre-frontal cortex (mPFC) has been associated with the mechanism that starts the attribution of beliefs and desires[22] as well as the processing of relevant social and emotional information about other issues[23]. It also participates in later reflections and complex mental elaborations about inferred mental states[24].

The superior temporal sulcus (STS) has also been involved in the representation of the actions of others[25]. It has been systematically proved by its activation during the interpretation of the actions and the observation of social animations[26].

In the same vein, the Temporal-Parietal Junction (TJP) has been associated with the representation of thoughts or beliefs of other subjects but not with other mental states such as feelings or body sensations[27, 28]. This notion has received some additional support through the use of tasks based on social animations or associated with the inference of intentions[26]. Additionally, it is important to note that the functions of the ToM cannot be reduced to a unique level of processing. For example, while TPJ has been associated with the detection and explicit processing of mental states, STS participates in the implicit management if this information, both being necessary components

Table 1. Clinical Measurement of Social Cognition

Theory of Mind (ToM)

The shortcomings of the the Theory of Mind can be perceived in different ways at the clinical level. The difficulty to decipher the mental states of other people and act accordingly, the mistakes in interpreting language, and the incapacity to detect one's own poor adjustment to the social context could be isolated events or the core element of insufficient social behavior.

The ToM can be evaluated by showing a vignette of an interaction or dialogue, and hoping that the patient correctly identifies the wrong attitudes and makes inferences on the intentions and feelings. We offer an example below of a question of faux paus according to what was assessed per Bertoux's mini-SEA (the real phrases and questions included in the test are not displayed here):

"John is finishing up his first dinner with his future mother-in-law. She has been cooking all day and trying to make a good impression on her daughter's fiancé. At the end of the meal, John smiles and says:
Thank you very much for such a delicious dinner. The chicken was wonderful, obviously not as good as my mother's chicken, but thank you for the effort."

(Questions for the patient)
Did anyone say anything inappropriate?
Who said it?
Why was it inappropriate?
How do you think John's future mother-in-law felt?

Social Perception

At the clinical level, decrease in social perception is perceived as a failure to classify facial or kinetic signs as an expression of happiness, sadness, rejection, etc. This can be subjectively detected when inappropriate responses to the social clues have become frequent.

For example, when patients frequently arrive late for their doctor's appointments, or they make inappropriate requests of their doctor, and they do not perceive the facial expressions of disapproval to their own behavior, we might suspect that this cognitive domain is impaired.

Here we show how the correct identification of the facial emotional expressions can be assessed:

"Look at the following face (or group of faces) and identify the facial expression shown by the person in the image as one of the emotions at the bottom of the image."

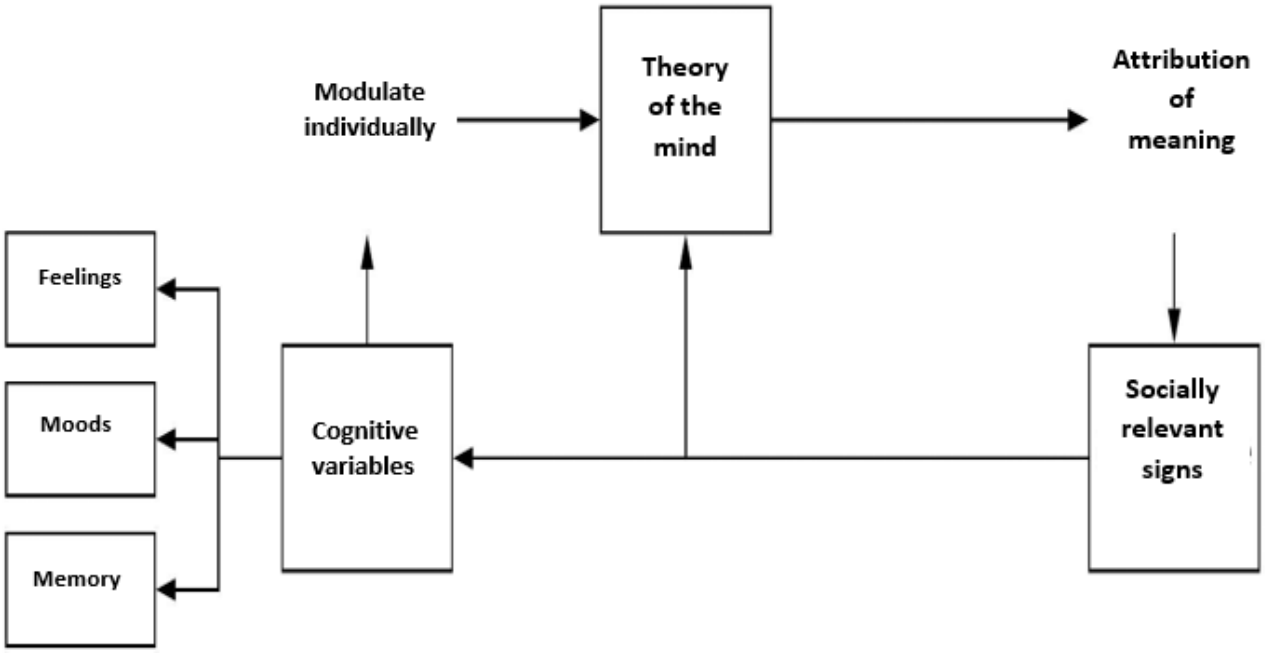
Happiness - Fear - Anger - Sadness - Surprise - Dislike - Neutral

to predict behavior[29].

These precise conceptual distinctions, so commonly used, could partially explain the wide variety of available evidence. Additionally, the overlap among regional functions should imply a greater functional and neuro-dynamic focus potential instead of structural localism.

Figure 2 shows an illustrative simplification of how the individual cognitive variables influence the interpretation of social information during the ToM process.

Figure 2.



Empathy

Refers to the generation of an emotional response in the observer in front of situations that affect other subjects. This may correspond to the same emotion, in which case the phenomenon is known as affective resonance. If the response corresponds to another, different feeling, such as anger when observing a person being publicly humiliated[4, 30]. It is an essential component if the human emotional experience and the social interaction because when an observed mental state is understood and affective responses are generated, there can be pro-social and cooperative behaviors[31].

When this type of behavior is studied, the imitation of the body posture and the movement (chameleon effect) when performing a collaborative task with a stranger has been demonstrated, which improves the quality of the interaction. In fact, it has been shown that a chameleon effect is stronger in more emphatic subjects[32]. It was sensed early on, from the definition of the concept by Theodore Lipps, that the "internal imitation" of actions play a relevant role in empathy[33].

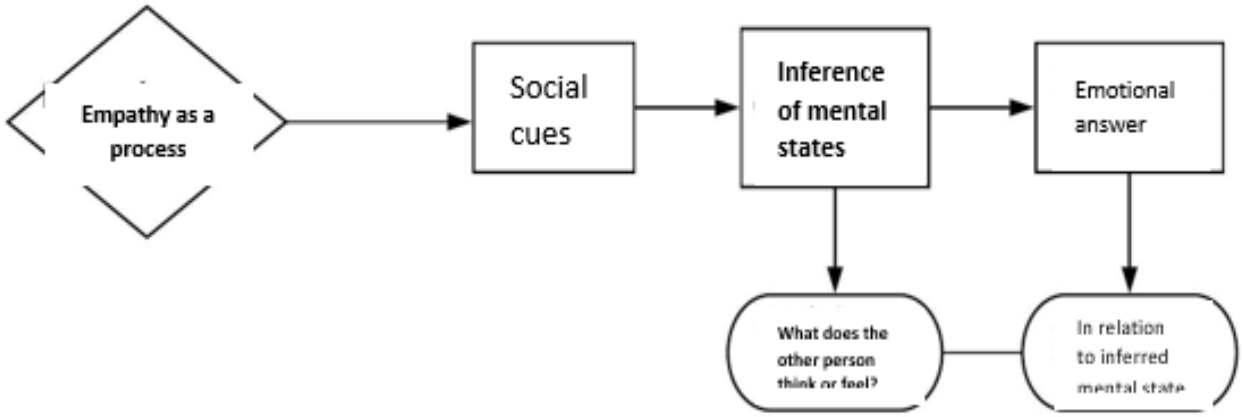
When looking for neural correlations in the processes previously described, recent studies have shown that the performance of tasks associated with consciousness of emotions and actions both of our own and of others is associated with different areas of the brain, such as the somatosensorial cortex, insular cortex, cingulate cortex and the visual cortex[34]. This provides an initial idea of the wide diversity of neuronal resources involved.

Additionally, the amygdala has an important role in the central processes involved in empathy. Beyond their relationship with emotional responses, the long term memory, the identification of the affective content of a stimulus and the perception of the orientation of a look[31], it probably exercises a systemic neuro-modulating function, as its activation precedes the participation of other areas during the observations of expressive faces[35]. Given the

great relevance of this area in social cognition and empathy, its role has been studied in conditions such as autism disorder spectrum, which show compensatory activation of unrelated cortical areas during the processing of facial images[36], while local activity on the amygdala during this type of task has been shown to be greater[37]. Taking into consideration the evidence, some authors have proposed than the disturbances of the development of the amygdala as a neuroanatomical and functional substratum of the socio-cognitive deterioration in these patients [38].

The Mirror Neuron System (MNS) is another concept commonly used to understand the neural mechanism that underlies empathy. This term was coined after the observation of certain neurons in the premotor cortex of monkeys which are discharged when they observe an action performed by another animal or the researcher, corresponding to the neural representation of the observed behavior[39]. After, in the initial conceptualization, this system linked the observation and the execution of the motor actions[40], but further studies that use functional magnetic resonance images (fMRI) have shown that these properties are not exclusively present in visual systems, but also in auditive and language functions[41]. Curiously, when observing people subjected to pain, the activation of the insular and cingulate cortex have been registered, but his activation is registered by negative perceptions about the affected person[42]. Thereafter, a complex combination of actors determine empathy as a process, and the activity of different brain areas that participate in the performance of empathy tasks[43, 44] providing a neuro-dynamic explanation for the variability of the behavior. **Figure 3** illustrates the flow from social cues to the inference of the mental state and the generation of a related emotional response.

Figure 3.



Social Perception

Social Perception has been defined as the capacity to perceive the mental states of others based on behavioral signals[45], and it is considered to precede more complex processes that rose more recently in the human development [46]. The perception of the expressive actions of the movements is an important element for the understanding of the social environment[47] and regulates human behavior. In fact, the mere observation of an action in another person unleashes an anticipated action in the observed based on the inference of desires and intentions[48]. Table 1 provides an example of the situations in which a compromise of social perception and a method for its measurement may be suspected. For a long time, the study of this concept has been driven by the following axiom: we cannot directly perceive the mental states of other people and must execute varied mental abilities to infer them (mind reading). But recently, this notion has been questioned by the direct social perception theory, which has been backed by

models such as Bayesian predictive codification, which suggests a probabilistic inference that involves different levels[15, 16].

The role of the amygdala has generated a particular interest given its participation in the discrete neural representation of certain emotions[49]. When fast processing is required[50], the view is oriented to facial points with social relevance, such as the eyes [51, 52] Therefore, this area codifies the emotional prominence of social information[53]. In the same vein, it has been shown that the orbitofrontal cortex participates in the perception of rewards associated with environmental lanes, participating in relevant aspects of planning and regulation of behavior in humans and primates[54].

Conversely, the fusiform gyrus includes many areas particularly involved in the visual aspects of social perception[55]. Certain areas are associated with a selective response to body or facial stimulus[56] which participate in complex processes, such as the recognition of identity or intention[57]. Nevertheless, the codification of social information must not be understood as a static and anatomically circumscribed phenomenon. STS has shown to receive auditive and visual afferences to extract and represent relevant and dynamic social information.

In the same vein, the perspective of neural networks has provided additional information about the role of the limbic lobe and other subcortical structures in facial interpretations. A meta-analysis that considered 105 original articles and 1600 subjects concluded that the processing of faces with emotional expressions is related with the activation of the visual, limbic, tempoparietal and prefrontal cortexes, as well as the putamen and cerebellum activity. While the cerebellum and the visual cortex are involved in the processing of all the expressions, happiness, fear, and sadness recruit the amygdala, and anger and disgust selectively recruit the insula [60]. Once again, the data mentioned provides evidence about the diversity and complexity of the neuronal resources involved in social perception.

Frontal-temporal dementia is a well-studied example from the perspective of the condition. In these patients, the detection and the categorization if the emotions have been related to the volume of gray matter in the anterior temporal lobe and the frontal gyrus. Additionally, when compared to healthy controls, patients show a higher functional connectivity in the mentioned areas of interest [61], suggesting the existence of functional compensatory exchanges.

Figure 4 shows the selection and categorization of the environmental information as critical steps in social perception.

Figure 4.

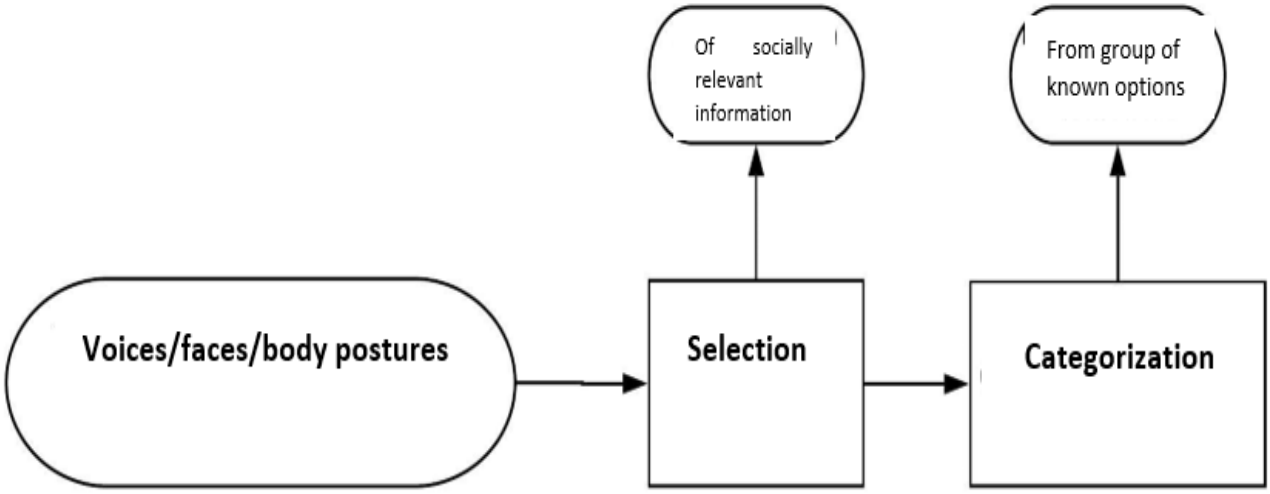


Table 1 provides an example of a clinical compromise of the Theory of Mind and how this domain is evaluated.

Conclusions

The study of social cognition implies a challenge at the conceptual level. In this article, we have proposed social cognition as an integration of the processes by which the subjects receive social signals (social perception), infer psychological states in other people (Theory of the Mind) and finally, generate emotional responses to motivate and regulate behavior (empathy). Even if this schematization can be conceptually improved, we propose it as a starting point to evaluate these cognitive functions in clinical populations.

In this review, we have intentionally omitted a deeper characterization of social behavior to focus our attention in those realms whose clinical evaluation is more practical, even recognizing that an additional effort must be done to provide an operational description of the behavioral realm.

The growing interest in establishing this domain as a research focus opens a great number of opportunities to generate evidence concerning patterns of specific disease in relation to both natural history as well as therapy.

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