

Neuronal and Developmental Dimensions of Mentalizing and its Connections to Executive Functions

DOI: 10.57642/AJOPSY911

Azzeddine Charki **Benaissa Zarhbouch** **Chaimae Bouchala** **Fatima Zahra Meklaoui**
charkiazzeddine@gmail.com b.zarhbouch@usmba.ac.ma chaimae.bouchala1992@gmail.com fatiza.meklaoui@gmail.com
Faculty of Letters and Human Sciences Ain Chok, Hassan II University, Casablanca, Morocco Faculty of Letters and Human Sciences Dhar Al Mahraz, Sidi Mohamed Ben Abdellah University, Fes, Morocco Faculty of Letters and Human Sciences Sais, Sidi Mohamed Ben Abdellah University, Fes, Morocco Faculty of Letters and Human Sciences Dhar El Mahraz, Sidi Mohamed Ben Abdellah University, Fes, Morocco.
Received: 29/04/2024 Accepted: 24/05/2024 Published: 30/06/2024

Abstract

Daily life of people is based on a framework of cognitive abilities, emotional skills, and social competencies that enable them to engage in social communication and establish personal relationships. Mentalizing abilities form part of these mental processes, commonly referred to as social cognition. The development of mentalizing and abilities of social cognition in general is often marked during the pre-school age when individuals exhibit cognitive aptitudes that allow them to understand the mental states and behavioral responses of others in a simple manner. Later, these abilities undergo significant development until reaching maturity in advanced mentalizing. Thus, advanced mentalizing enables an understanding of complex mental states that underlie complex social behaviors and interactions. These abilities dependent on specific neural pathways within the social brain network, which differs in activation compared to other cognitive functions, such as executive functions. In this context, this paper aims to theoretically study mentalizing and approach it conceptually. It precisely defines its concepts and monitors the trajectory of its various capabilities and the development of inferential levels within it. Additionally, it identifies the network of neural foundations on which its neural functioning relies. Furthermore, it clarifies the nature of the relationship between mentalizing and cognitive processes, particularly executive functions.

Keywords: mentalizing, social cognition, mental states attribution, socio-cognitive capacities, executive functions

Introduction

Unlike other species, the daily social life of people is built upon and relies on a framework of cognitive abilities, emotional skills, and social competencies that enable them to engage in emotional and verbal-social communication, and interpersonal relationships, as well as acquire the necessary social knowledge to participate, interact, or adapt flexibly within the social environment. Moreover, it empowers them to belong to social groups, and live collectively in different social and cultural settings. It is possible that the abilities of understanding, inferring, and attributing mental states to oneself and others - known as mentalizing (Gilead & Ochsner, 2021) form part of these mental capacities referred to as socio-cognitive processes or “social cognition”, which actually represent the sum of our mental abilities that we utilize in thinking about the self and others, or in “perceiving, interpreting, and processing social information” (Ostrom, 1984, p. 176) related to the social world. Mentalizing constituted a central mechanism in human socio-cognitive functioning, which has a fundamental and important role in daily social interactions, as well as building judgments and social decision-making (Civai & Sanfey, 2019), causal attribution and interpretation of the facts of behavior (Fiske & Taylor, 2017; Frith & Singer, 2008). Moreover, it has a close association with cognitive functions, especially language and execution functions (Csulak et al., 2022) that enables cognitive monitoring, as required by unusual situations, during problem solving, planning, or controlling the flow of social relationships and decision-making. These cognitive functions develop relatively parallel to the capabilities of the mentalizing during the preschool age (Sabbagh et al., 2006) which neurologically intersects with the prefrontal cortex (Friedman & Robbins, 2022; Stuss et al., 2001). The social cognitive system generally requires the activation of a specific network of regions and neural connections located in the social brain (Henry et al., 2021; Moessnang et al., 2020). Additionally, as it represents metacognitive ability, allowing for the awareness and understanding of mental representations and thinking about the same mental states (Duval et al., 2011; Frith & Frith, 2003), in light of knowledge derived from personal and social experiences, which derive their legitimacy from the psychology of common sense. In this context, this paper aims to theoretically study mentalizing and conceptualize it by highlighting its development as a concept expressed through interdisciplinary intersections. This is an attempt to understand and approach the growth and development of its cognitive abilities, and reasoning levels, and identify the network of its rules (substrates or bases) and neural connections, as well as its relationship to cognitive functions, especially executive functions.

Mentalizing: Conceptual and Theoretical Determinations

The study of the phenomena of “inference and attribution mental states or mentalizing” originated from an experimental study by Heider and Simmel (1944) on causality and social perception (Etchepare & Prouteau, 2017). The term mentalizing was introduced for the first time by John Morton and Uta Frith (1989) in contemporary cognitive research. However, the actual interest in this socio-cognitive process, also referred to as “Theory of Mind (ToM)” as a well-defined scientific concept, emerged at first with Woodruff and Premack (1978) in the field of ethology, aiming to explore the chimpanzees’ ability to understand mental states and anticipate actions and behaviors (Wellman et al., 2001). Since then, mentalizing has become a central concept in the field of social cognition (Henry et al., 2021), studied alongside socio-cognitive processes and phenomena. Initially, it was approached as a term that almost constituted a distinct scientific concept in cognitive research, focusing on the ability to attribute mental states to oneself and others. It was associated with various synonyms, such as folk psychology, ToM, mindreading (Apperly, 2011), mind perception, perspective taking, and social understanding (Schaafsma et al., 2015). The

prevailing term was ToM, expressing an individual's capacity to understand the cognitive representations that can reflect false beliefs (Boucher, 2012; Wimmer & Perner, 1983). However, its current approach with Frith encompasses not only the cognitive aspect related to understanding cognitive mentalizing but also perceptual, emotional, desires, and motivational aspects (Boucher, 2012). In recent years, mentalizing has become a widely used concept in the field of contemporary cognitive research, and it is interchangeably used with the ToM in leading psychological and neuroscientific studies (Gilead & Ochsner, 2021). The initial exploration of this concept within ethology and cognitive psychology led it to intersect with many other scientific disciplines, such as developmental and clinical psychology, cognitive psychopathology, biological psychiatry, and philosophy of mind. Additionally, cognitive neuroscience has greatly contributed to its development and flourishing in cognitive research in general (Gilead & Ochsner, 2021). Currently, mentalizing is known as a socio-cognitive process that is fundamentally central to social cognition. It allows individuals to cognitively attribute and assume that others, both similar and different to themselves, possess mental states, beliefs, emotions, or motivations that are similar or different from their own. It enables the inference and prediction of thoughts and expectations about what is happening in the minds of others to understand and anticipate their behavior. In this sense, mentalizing, based on hypothetical and unobservable facts, essentially resembles theory building. However, here it is more intuitive than scientific, serving as an intuitive psychological-social theory - that is also called as ToM - It reflects spontaneous psychological constructions and deductive inferences made by the self about "how the mind works" (Apperly, 2011). It is stimulated through daily experiences of interacting with others' minds, aiming to engage with individuals, understand their mental states, and interpret their behaviors. It is worth noting that mentalizing forms a complex cognitive system that allows individuals, automatically and reflexively, to judge and mentally reason about others' mental states and behaviors. The processes involved in mentalizing include reading, guessing, interpreting, reasoning, and anticipating the target mental actions and events, and responding to them by adopting cognitive attitudes or behaviors (verbal expressions or movements). In other words, mentalizing engages in several processes that range from recognition and reading to interpretation, judgment, and anticipation. Its purpose is to perceive, understand, infer, and attribute mental states, whether cognitive or affective, to oneself and others, as well as to anticipate and interpret them. Moreover, through mentalizing, one can interpret people's behaviors and anticipate them (Mitchell, 1997). These cognitive and affective states actually constitute different mental constructions that emerge in the mind at that moment, collectively expressing beliefs, perceptions, plans, purposes, motivations, emotions, and effects (Flavell, 1999). Through these mental constructions, individuals think and interpret people's behaviors and anticipate them in similar or new situations. To achieve these various goals, mentalizing is based on abstraction and inferred assumptions about what is happening in others' minds and the thoughts and mental events, underlying their different behaviors. It deduces and infers these mental states, whether related to oneself and experienced by the individual or related to others and inferred through facial expressions, tone of voice, body movements, eye contact, or gaze direction (Wu et al., 2020). These mental states are consciously recognized independently of the self, functioning as a metacognitive mechanism in which thinking observes its own processes, depending on their nature and source.

Development of mentalizing

The preschool stage, which is approximately the first four years of age, represents an important period in the cognitive and social development of a child. During this stage, the child undergoes various changes that significantly influence their mental abilities, specifically, higher cognitive functions (executive functions) and mentalizing emerge (Perner

& Lang, 1999). These mental abilities, especially mentalizing, enable the child to understand the thoughts and different emotions of others and build intuitive knowledge about the psychology of others and oneself. However, the child's understanding at this stage is still simple and not as complex as that of an older child or adult. Although the child may be able to differentiate between mental phenomena as abstract and unobservable states and physical phenomena (objects and material entities) as tangible and visible, their understanding remains limited and simplistic (Baron-Cohen, 1995; Korkmaz, 2011). Additionally, while the child can perceive intentions, beliefs, or emotions (Wellman, 2014), they cannot accurately and realistically infer false beliefs until around the age of five (Miller, 2009). At this age, they become capable of applying the principle of psychological causality in their thinking. Therefore, they can theoretically connect mental life and behavior while understanding people, predicting their social actions, and observing their social understanding of others. This explicitly demonstrates the presence of a consistent mental perspective where mental phenomena and actions are considered as causes of behavior (Leslie et al., 2004). The child's knowledge of this socio-psychological world comes from their perception of the thoughts, beliefs, goals, expectations, desires, emotions, and incentives of themselves and others. These factors are assumed to underlie complex social behaviors and interactions. However, the development of these mental abilities does not occur all at once; it progresses gradually as the child grows older, passing through successive stages. In the study of mentalizing development, it is important to differentiate between several cognitive dimensions, mainly characterized by levels of reasoning that range from simple to complex, and are related to the target mental state (self or others). Experimental tests have been designed to examine these different levels of mentalizing complexity, reflecting the individual's performance at each level (first and second order ToM or advanced ToM). Researchers, specifically Wimmer and Perner (1983), were credited in developmental psychology for developing the first psychological test (classic false-belief task; Max and chocolate) that measures first-order mentalizing ability (or first order ToM; Wimmer & Perner, 1983), followed by another test measuring second order mentalizing (Wimmer & Perner, 1985). Each test represents an experimental situation that reflects a scenario between two individuals regarding a specific subject that is assumed to be known in the other person's mind and can be known by the subject. In this context, the levels of mentalizing are defined based on the reasoning processes required to handle mental states and behaviors as social information. These levels include zero order direct knowledge of reality (I believe in something), first order awareness of the knowledge of others (I believe that someone believes ...), and second order awareness of the knowledge of others through the knowledge of another person (I believe that someone believes that someone else believes...) (Charki & Ettouzani, 2021; Duval et al., 2011). The third level (higher-order ToM) involves advanced and highly abstract abilities (Gabriel et al., 2021). These abilities develop sequentially, and by the age of four or five, the child typically achieves first level mentalizing (Flavell, 1999; Wellman et al., 2001; Wimmer & Perner, 1983). However, the awareness of second level mentalizing does not occur until around the age of 7 or 8 (Miller, 2009), and third order mentalizing is significantly advanced by the age of ten (Leslie et al., 2004; Miller, 2009; Perner & Wimmer, 1985), continuing to develop throughout late adolescence (Dumontheil et al., 2010). Thus, during this stage, the child's abstract and high-level executive abilities mature, enabling them to understand and perceive the minds of others and infer their internal states at different levels. These cognitive abilities are crucial for effective communication and social understanding (Miller, 2009). And enhancing their quality through empathy and daily interactions within various social organizations (family, school, work) (El Haj et al., 2016; Green et al., 2019).

The neural bases and substrates of mentalizing

Considering mental states is a complex cognitive process carried out by the mind in its quest to understand others and make inferences about their mental states and predict their behaviors. This cognitive process is primarily based on material substrates, forming a network of brain regions and structures - the social brain - that dynamically activate and interact in social situations. Many of these brain structures, specifically the bilateral temporo-parietal junction (TPJ), precuneus (PC), and medial prefrontal cortex (mPFC) (Kliemann & Adolphs, 2018; Schurz et al., 2014), form a core structure for mentalizing (Gilead & Ochsner, 2021). Other structures such as the posterior superior temporal sulcus (pSTS), amygdala/limbic system (LS), posterior cingulate cortex (PCC), and orbitofrontal cortex (O-FC) also play complementary roles (Bejanin et al., 2016). Recent studies have focused on distinguishing between components of mentalizing - cognitive mentalizing and affective mentalizing - and investigating their separate neural activation. Cognitive mentalizing, which represents the understanding of cognitive mental states (representations, beliefs), involves the functional activation of the mPFC, pSTS, and TPJ (Gilead & Ochsner, 2021). On the other hand, affective mentalizing, which pertains to the understanding of affective mental states (emotions and feelings) (Shamay-Tsoory et al., 2010), primarily involves the ventromedial prefrontal cortex (Dvash & Shamay-Tsoory, 2014). These neural structures can be positively influenced by age, as they continue to grow and develop over time, including late adolescence. However, they can also be negatively affected by clinical pathologies, exhibiting atypical growth patterns and functional activity in clinical populations, especially individuals with autism spectrum disorders and schizophrenia (Lombardo et al., 2011), compared to neurotypical individuals. For instance, the right RTPJ shows weak activation in individuals with autism spectrum disorders compared to neurotypical individuals (Lombardo et al., 2011; Moessnang et al., 2020).

Mentalizing and executive functions

Executive Functions, or more precisely, cognitive monitoring mechanisms (Crone & Steinbeis, 2017; Diamond, 2013), are among the cognitive functions that allow individuals to regulate and self-monitor cognitively during their encounters with new and complex situations and contexts. Their strength and effectiveness manifest in controlling impulses, inhibiting automatic responses, modifying thinking strategies, controlling the flow of information to prevent dominance of inappropriate information, and directing cognitive resources towards pre-planned goals (Collette, 2004) in order to make decisions and accomplish them. Thus, they constitute high-level cognitive abilities that are essential for behavioral control (Jurado & Rosselli, 2007), intervening in complex tasks, problem-solving, decoding new and complex situations, and facilitating adaptation and compatibility. These cognitive functions represent a multidimensional and component-based cognitive system, encompassing several cognitive processes that collectively involve updating information in working memory, action initiation, organization, flexible shifting, inhibitory control, planning, and decision-making (Diamond et al., 2002; Miyake et al., 2000). Although theoretical models of executive functions have greatly differed in defining their components and specifying the number of their core processes, given the diverse perspectives in cognitive psychology and cognitive neurosciences. The established and prevailing approach seems to consider executive functions as a cognitive system comprising three central functions, primarily represented by working memory, mental flexibility, and inhibition (Diamond, 2013; Miyake et al., 2000). It is noteworthy that these three functions constitute the core components of executive functioning (Diamond, 2013) and are involved in every executive-based cognitive control. Where working memory represents a limited cognitive capacity that allows for temporary retention,

manipulation, and processing of information in the mind during cognitive tasks, in order to support cognition and behavior (Baddeley et al., 2021). Inhibition, both cognitive and behavioral, refers to an individual's cognitive ability to direct and focus their attention on important stimuli while disregarding distractive ones (Moreau & Champagne-Lavau, 2014), as well as inhibiting dominant, automatic responses and maladaptive behaviors in various situations. Cognitive flexibility, another central mental process in executive functioning, represents a type of readiness in which an individual's cognitive schema selectively changes in response to appropriate environmental stimuli (Scott, 1962). It allows for flexible shifting and transition from one cognitive state to another, enabling the ability to focus on and accomplish multiple tasks simultaneously while adapting to their requirements and conditions. However, the achievement of cognitive flexibility relies on the prior functioning of the aforementioned two functions, given their fundamental and effective roles (Diamond, 2013). These various executive functions are generally crucial for daily life, not only in achieving self-cognitive monitoring required and elicited by different activities for adapting to new situations and managing everyday life circumstances, but also for regulating emotions and engaging in mental reasoning processes for cognitive and affective states of others, reflected by mentalizing activity (Sabbagh et al., 2013). Moreover, it significantly contributes to enabling it to function well (Pellicano, 2007). This can be seen in the individual's observation while thinking and being aware of their thoughts, intentions, and emotions towards the behaviors and mental states of the other. In fact, this meta-cognitive thinking requires the intervention of higher-level cognitive processes (such as organization, transformation, and updating) to monitor and manage the mental states between the self and the other. Thus, if the individual's thoughts and feelings about oneself constitute a fundamental stage in understanding what others think and feel, according to the theory of simulation (Gordon, 1986), inhibiting these self-related mental states and their awareness is necessary to access the mind of others, comprehend their thoughts by inferring intentions and ideas based on behavior and traits, and perceive their mental states independently of one's own. Therefore, we find that mentalizing activity is closely related to the process of inhibition and other components of executive functions (Bull et al., 2008; Carlson et al., 2002). This connection has also been notably observed in some empirical studies (Carlson & Moses, 2001; Laillier et al., 2019; Otsuka et al., 2021), which have found a strong correlation between inhibition and mentalizing, including its affective component (Laillier et al., 2019; Otsuka et al., 2021). Inhibition intervenes in its related capacities, including the understanding of affective states and emotions. Moreover, it significantly influences the emergence and expression of knowledge and other mental states in general (Carlson et al., 2001). The same process occurs with the flow of transformation or mental flexibility during thinking about the behavior of others and interpreting their mental states. It allows individuals to transition flexibly from thinking about a particular subject (person, behavior, mental state, decision, etc.) to another without losing their specificity. This is evident in the smoothness and flexibility of the mind during the completion of various tasks (such as continuous discussion or decision-making) and the transition between them based on the requirements imposed by social situations and others. As for the capacities of updating or working memory, they are necessary for the functioning of mental processes as a whole. They contribute significantly to their development and maturation during the preschool phase (Carlson et al., 2001). Therefore, the ability to consider different and conflicting perspectives, for example, is necessary to acquire knowledge about mental states and express them. In this regard, working memory plays an important role in accomplishing mental tasks and generally intervenes in securing and storing social information (mental states, behavior, characteristics, etc.) while moving and processing it in the mind (Carlson et al., 2002). On this basis, this aspect of working memory, according to Mayer et al. (2012), serves as a social working memory within the overall working memory

system (see Baddeley & Hitch, 1974). It specializes in storing and processing social information and actively engages in the process of mental inference or cognition in general (Meyer et al., 2012, 2015). In other words, examining mental states and attributing them to the self and others requires individuals to access and possess information related to the person (self or others) and maintain and mentally manipulate it in order to reach a type of knowledge and inference about their relevant mental state (Meyer et al., 2012). Consequently, all these aforementioned processes performed by the mind naturally fall within the working memory system. In light of these different data, executive functions may generally play an important role in mental processes. The engagement of these processes in an individual is connected to understanding the behaviors and mental states of others (such as false beliefs), which actually requires the ability to withhold one's own knowledge (inhibition) to place oneself in the position of the other person (shifting attention or flexibility), and then consider the main elements of the event, where these pieces of information can be monitored and updated for the preparation of mental inferences (Austin et al., 2014). On the other hand, mental processes can constitute a prerequisite for executive functions (see Perner & Lang, 1999). Achieving and performing many of these executive tasks involved in the process of inference requires a certain level of mental processes from the individual, in order to think about their plans, goals, and decisions, and be aware of them (Wilson et al., 2014). Based on the previous evidences, it can be concluded that the relationship between mental processes and executive functions remains valid at significant levels for several reasons. The first of these manifestations are evident in the interconnection of both in early developmental stages, where some of their abilities appear relatively synchronized in children in the preschool phase (Sabbagh et al., 2006). In addition, the maturation of brain structures that are shared by both mental processes and executive functions occurs within the prefrontal cortex (Friedman & Robbins, 2022). On the other hand, the latter is associated with the pathological dimension and atypical engagement of both, as they exhibit impairments in individuals with certain clinical and neuropsychiatric disorders such as autism spectrum disorders and schizophrenia spectrum disorders (Austin et al., 2014).

Conclusion

Based on the previous discussion, we can indicate that mentalizing, as a central cognitive process in social cognition, initially constituted a distinctive subject in developmental and cognitive psychology. However, in recent years, it has become a broad topic of research and investigation, attracting the interest of many researchers in various scientific disciplines such as social, developmental, and pathological cognitive psychology, psychiatry, and social neuroscience. These disciplines approach mentalizing from different perspectives. The study of mentalizing encompasses its various cognitive (cognitive and affective) components, the cognitive foundations upon which it is built, and the neural mechanisms that are involved in neural activation related to the elicited tasks (Apperly et al., 2009). Research in this regard generally suggests that the acquisition process of its cognitive components and reasoning levels (simple or complex) is governed by specific developmental trajectories. These trajectories explicitly emerge around middle childhood and continue to develop until adolescence. Mentalizing may form a complex cognitive system that includes multiple dimensions and components (cognitive, affective, automatic, explicit, primary or secondary levels, etc.). The different mental processes rely on material supports reflected by a specific network of brain structures and neural connections that occur in the human brain. Furthermore, mentalizing is closely related to executive functioning abilities, and the nature of their relationship is considered reciprocal. It has been shown that the latter plays an important role in the functioning and maturation of mentalizing abilities. However, the research and studies in this field have sparked a significant debate among researchers due to

their relative differences and variations. As a result, some research outcomes have led to conflicting interpretations. The first perspective supports the assumption that mentalizing abilities are subservient to cognitive abilities (Duval et al., 2011), particularly executive functions, while the second perspective emphasizes that they are two independent mental systems that also intersect and have reciprocal relationships (Austin et al., 2014; Wilson et al., 2014). Moreover, impairment of these mental abilities, especially mentalizing, can have negative effects. For example, in neurodevelopmental disorders such as autism spectrum disorders, attention deficit and hyperactivity disorder, language and communication disorders, and schizophrenia (Charki & Ettouzani, 2021; Korkmaz, 2011), lead to deficiencies in daily social communication skills and disturbances in social behavior among individuals with these disorders (Charki & Ettouzani, 2021; Mazza et al., 2017). It also negatively impacts social learning, adaptation, and social functioning in general (Chiu et al., 2022; Şahin et al., 2018). In light of this, recent research and clinical interventions have focused on developing new treatment and intervention plans known as cognitive and psychosocial rehabilitation, specifically targeting social cognitive functions including mentalization. These interventions have become the goal of clinical diagnosis and intervention approaches, such as Mentalization-Based Treatment/Therapy (Allen & Fonagy, 2006, Bateman & Fonagy, 2010), which have proven to be highly effective in treating certain mental disorders and borderline personality disorders in particular.

Declarations

Conflict of interest : The authors declare that they have no conflicts of interest.

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