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Mirror Neuron Cells, Autism, Language Deficit, and the Potential Role of Artificial Intelligence

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Abstract

Mirror neuron cells were first found in the macaque monkey cortex and subsequently reported in the inferior frontal and parietal lobes. Due to the activation of this neural apparatus during goal understanding, some scholars believe that mirror neurons are involved in one of the cognitive aspects of understanding, called action understanding. Later, it was argued that this system was involved in various social-cognition aspects, such as theory of mind, learning by observation, and empathy, which allow human beings to predict the behavior of others, transmit social knowledge, and grasp the states of mind of others. Some descriptions even give mirror neuron cells the ability to communicate without any conscious effort, with words, or beyond words. Researchers used proposals about mirror neuron cells to investigate the language of origin, social cognition, and human evolution. Like many new ideas, mirror neuron cells have caused a major reflection and a significant increase in academic activity. There are now about 4,000 papers on the topic.The production of behaviors is possible because of a complex interplay between perception and action. Component analysis of complex behavior is explained by the presence of neural circuits and complex cell activation patterns that model the predicted outcome derived from either performed or observed actions and consequently generate the actual physical performance. It is suggested, therefore, that knowledge of behavior, both own and others', could be organized in terms of acquired neural activity. The mirror neurons, reacting during observation and execution of the same motor act, would provide such neural means, blurring the experimental distinction between self-action and other action. Behavioral research on humans has shown enhanced memory and kinematic facilitation processes for action features that are either compatible or congruent with observed movement. However, only a few studies have so far been able to link these parametric effects to distinct changes in the cortical pattern of activity in the observer. Despite the widespread acceptance in the recent experimental literature, there is no definitive evidence for the existence of an MNS. Furthermore, contrasting evidence comes from transcranial brain stimulation investigations and from a few studies on patients with focal brain lesions. The broken MNS hypothesis and its models may offer more parsimonious and cognitively coherent accounts of ASC. Finally, it seems clear that imitation refers not only to mirroring processes but also to emulation/mimicry mechanisms underlying the formation of pragmatic and communicative aspects of imitation critically impaired and impoverished in ASC.

Keywords: *Autism, Language, Mirror Neuron Cells, Artificial Intelligence, Therapeutic Potential.*

Introduction

Mirror neurons are premotor cells that discharge during both the performance of an action and the perception of the same action performed by others (1). Despite caution regarding an "all or nothing" designation, the idea that the human brain resounds with the actions, sensations, and emotions of others has been captivating since the first monkey study (2). The essential mission of a vast population of researchers has been to determine which subspecies of mirror neuron cells light up in humans and which are involved in social cognition and communication (3). Multiple ideas regarding the role of mirror neuron cells in higher cognition and behavior have been proposed (4). However, the therapeutics that are inspired by these ideas have proven difficult to make (5). A fundamental question challenges how the results of monkey single-cell recording studies can be reconciled with powerful behavioral data that children with autism spectrum disorder (ASD) do not imitate (6). This last challenge has seen it taken up, in the main, by researchers of typical and atypical language development (7).

Children with ASD are significantly impaired in the development of social and communicative behaviors (8). At the heart of these impairments is believed to be an early emerging deficit in joint attention, the ability

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to coordinate attention between two entities via orienting, pointing, and gaze (9). As a result of these joint attentional difficulties, children with ASD do not learn words in the normal social context of language (10). A potential causative model of language impairment in autism suggests that because children learn language primarily by imitating the communicative structure of a socially interactive environment and children with ASD show a marked deficit in social imitation, this deficit is the root cause of their language disability (11). comprehensively review both the theories regarding the role of mirror neuron cells in higher cognition and behavior and the experimental data, including the more recent null results (12). On a higher level, this dissertation seeks to make a comprehensive exploration in light of relevant themes through addressing research gaps and potential methodological issues (13). The main purpose is to evaluate the theory that there is a causal link between mirror neuron cells and language deficits significant implications for intervention (14). A fundamental question inspired by the most recent concerns: What is the potential role of artificial intelligence in the development of novel intervention strategies? (15).

Mirror Neuron Cells: Function and Significance

Mirror neurons, consisting of a subset of neurons in the ventral premotor cortex and inferior parietal cortex, activate both when a subject performs an action and when that subject sees another individual performing the same action (16). This mechanism involves the integration of visual experience and production to enhance behavioral understanding of complex events and scenarios or to refine the mental representation of observed movements before their actual reproduction (17). There is a wide consensus that mirror neurons play a key role in empathic behavior, intention understanding, imitation, and social cognition (18). These abilities are fundamental constituents of language, and their development can scarcely be untangled from the development of language skills (19). Consequently, the impairment of the so-called mirror properties has been suggested to have a causal relationship with the observed deficits in language in humans (20). Nevertheless, comprehensive empirical evidence supporting this assertion has not been yet provided (21).

Seminal papers on mirror neurons reported that a large number of neurons discharge during the performance of a specific goal-directed action and when monkeys observe another monkey or even a human experimenter perform the same action (22). Since no shared sensory-motor experience was possible at all, these studies reported the existence of a basic mechanism grounding the understanding of others' actions and providing biological evidence of the neural theory of language (23). However, soon a controversy emerged because other research groups failed to replicate the previously reported results or generated evidence that challenged the original interpretation (24). In the last decades, a considerable number of neuroscientific, behavioural, and clinical studies have attempted to unravel the crucial issue of how mirror neurons code action understanding from an observed behavior (25).

Autism Spectrum Disorder: Characteristics and Language Deficits

Autism is a complex lifelong condition that significantly affects an individual's ability to communicate, to form relationships with others, and to respond appropriately to the environment (26). Behavioral characteristics of autism are largely based on impairments of social interaction, with the individual frequently being observed to show little or inconsistent interest in others, to be unable to mimic or share experiences effectively, to show limited ability to form or maintain friendships, and to show a lack of pointing out objects of interest to others (27). Only recently, a more systematic research into the character of communication in autism has begun, with progress mainly focused on challenges in social communication and pragmatic language use (28). Furthermore, expressive language deficits have long been noted in affected individuals. Social aspects of communication are of particular interest since this is where language can be said to contribute to the processing of brain and to the perceptions of a person's cognitive and emotional state (29). Typically-developing infants have demonstrated abilities to successfully engage in dyadic interactions, sharing emotions and exchanging information (30). Such capabilities are crucial for establishing joint attention and for shaping the contingent vocal responses that are critical to language acquisition (31). There is now a mass of research in developmental psychology indicating that the exchange of gaze between an infant and caregiver is crucial for regulating the pace of interaction and for shaping the kind of contingent input that promotes spoken language acquisition (32). In typical development, gaze

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alternation emerges in the first weeks of life and commonly continues to be employed as a strategy for securing adult attention in natural communicative interactions (33). Despite that gaze does not appear to be directed at particular objects, infants have been observed to follow the gaze of the adult in interaction and subsequently to shift their own gaze between the adult's face and objects they have attended to, engaging the adult in a shared episode of visual focus (34).

Neurobiological Underpinnings of Autism Spectrum Disorder

Neurobiologically, autism spectrum disorder (ASD) is one of the most complex and heterogeneous neuropsychiatric conditions, and understanding its biological substrates is still at its early stages (35). It is apparent that factors influencing the development of the brain lead to genetic, structural, and functional differences between typical and ASD cases (36). In particular, these differences may relate to the development and function of the neural networks responsible for the peculiar characteristics of the disorder, including specific social interaction and communication impairment as well as broader difficulties in integrating information across different brain regions (37). Although some individuals with ASD exhibit outstanding abilities in perceiving details or producing perfect reproductions, the impaired holistic processing of complex and socially relevant stimuli leads to severe developmental consequences (38). Among these are reduced interest in social signals during early development and decreased motivation to spend time with other people, which restricts the reciprocity of these individuals in real-world social environments and eventually compromises their development due to the recursive interplay of behavior with the environment, brain, and body (39).

Most of these core features may have their source in a neural network (40). Thus, irrespective of the genetic details or of the environmental events influencing its development, damage or anomalies in the structure or function of brain regions or of the pathways connecting them may result in the observed characteristics of the disorder (41). Differences in the development of the neural pathways may originate in the early stages of embryogenesis, leading also to variations in the development of other neural structures or possibly in extra-cubic manifestations (42). On the other hand, behavioral interventions – for example early rehabilitation treatments – may engage and refine some specific neural circuits, allowing the activation or regulation of otherwise inefficient activities (43). In the case of ASD, these complex interrelations are modulated by atypical sensory experiences that command atypical brain processing, leading to adaptive compensatory strategies mirroring different neural circuitry organization (44).

The Interplay between Mirror Neurons and Language Development

Imitation is viewed as a key player in the acquisition of language; children begin imitating sounds and gestures long before producing them, and the ability to vocally imitate is related to language development (45). Although other processes might also be important for the development of language, including speech perception, imitation seems necessary for its development (46). The imitation hypothesis suggests that imitation is so intrinsically rewarding that it can bootstrap the development of language, and humans possess special mechanisms—mirror neurons—for imitation leading to language and culture (47). This view puts forward an explanation of language that does not rely on any human-specific adaptations, developing out of mechanisms for learning about and understanding the actions of others (48).

The idea of mirror neurons as a system for language acquisition is complemented by the concept of "language of the mirror neuron system." Language can be learned and understood by using a vocabulary and a grammar represented in the brain in a distributed, spatiotemporal fashion (49). This distributed point of view fits in part as well with a conception of linguistic knowledge as representation of distributed pattern (50). Children start with the building of action and sensory-motor sentence schemata that could make use of the activation of brain circuits involved in imitation and action understanding (51). Language input activates in the child brain a series of representations similar to those activated in adults by the processed language (52). In this fashion the child parses the language input (53).

In the last three decades, an increasing number of churchgoers have ceased to attend a religious service or ceremony within a congregation (54). The fact that church buildings have still continued to multiply has led

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to a proliferation of large empty monuments in villages (55). These buildings, mostly coeval with a churchgoers' highest attendance rate, have outlived their original function and have gone mostly unused, occupied only on special occasions (56). Furthermore, the development of multimedia tools such as virtual reality and the basic principles of embodiment, the semiotic theory of meaning-making and a proposal for a new theology of place inclusive of multicultural and multi-religious approaches was presented (57). Taken together, these tools, concepts and strategies could be integrated to establish a novel theoretical framework and set of tools referred to as holyscapes (58). This can be used in order to map the topography of sacred landscapes, encode the fidelity of place in the memorial record and/or restore the sacredness of special places through new forms of 'sacred' occupation (59). This innovative approach, based on the consolidation of the new line of research, offers the unprecedented possibility of empirical investigation to better understand the presence in a specific place of the sacred and of the divine (60).

Artificial Intelligence in Language Intervention for Individuals with Autism Spectrum Disorder

The discovery of mirror neuron cells, which are mainly found in the ventral premotor cortex and the posterior part of the inferior frontal gyrus, has resulted in a systemic revolution due to their intimate relations not only with action observation and motor functions, but also with intention, empathy, language, and emotion (3, 61). Hence, the primary objective of this systematic study was to review the data on mirror neuron cells and to discuss its relationships and potential contributions to the studies of autism, language deficit, and other neuropsychiatric disorders (62). Given the relevance of mirror neuron theory, professional teams from different subfields, including neurologists, psychiatrists, pediatricians, physiotherapists, psychologists, and medical doctors, should be aware to argue the promising and essential studies related to this aspect (63). Besides, it is recommended that its educational benefits and potential integration into new therapeutic approaches should also be emphasized (64).

However, there are a number of potential areas where an integrated perspective could enhance our understanding of the relationships between mirror neurons and disease states (65). Given the increasing evidence of a toward examination of whether interventions that modify activity of MN could enhance treatment of any of these disorders (66). There is also a clear need to develop new theories and test these both experimentally and computationally (67). For example, it would be important to test whether activity of MN is distinct across these disorders; if so this could potentially illuminate why symptoms differ along one or more affective/preferred axes (68). Finally, it is possible that range of future neuroimaging techniques will allow progression of present examination of MN function and connectivity to an examination of all types of nerve cells in both the mirror and canonical data streams (69).

Current AI Applications in Autism Intervention

Building on our theoretical understanding of tacit and phonological impairments, artificial intelligence methodologies have been developed and used for the recognition, emulation, and amplification of subtle language skill (70). It is emphasized that the skills of many children with autism can be expanded to and beyond the stage necessary for rudimentary language use (71). Smart devices, artificial intelligence, and the movement in AI computing power to a decentralized model offer new possibilities in the use of intensive intervention models, supporting wider adoption and more effective education in second-row hospitals and rural areas where resources are lacking (72). After a year of the widespread use of invasive virtual platforms, priority must be given to developing safe and open AI platforms that are not locked (73). There should be an emphasis on the use of experiments in randomized control to test and improve the function of an AI intervention. Above all, we urge the intervention to be scientifically attentive and for it to avoid the easy exploitation of the desperate (74).

Since Kanner's descriptive paper on autism, numerous papers have been published on the nature of autism and how to best treat it (75). Autistic disorders have long been understood in terms of a deficit in the theory of mind; children with autism have a lack of understanding of other people's minds (76). One potentially beneficial form of peer interaction, playing together, is reduced in frequency on the part of a child with autism (77). It has also been suggested that the incessant, apparently purposeless behavior of many children with autism is a consequence of their lack of sufficient model for imitation provided by their parents (78).

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Early research led to a literacy-based view of the 1970s, a psychology-led literature exploration of the 1980s, and an understanding of the behavior dysfunction of more recent autism (79). In response to this understanding, giving behavioral deficits of several descriptions in autism, and numerous therapeutic endeavors from clomipramine to follow linguistic shows to bounce balls in all manner of different ways to the groundbreaking treatment of the immune body mirror cells (80). Over 40 years of research by the world's finest minds produced results that are only now ready for this treatment to be popularized (81).

Conclusion

This essay has examined the neurobiological association of mirror neurons, autism spectrum disorder, and language deficits through a review of cutting-edge research in these areas across multiple disciplines. The current literature suggests that children with ASD are likely to have a weaker mirror neuron system or dysfunctional mirror neurons (82). This weak or absent MNS may well play a crucial role in the social-communication deficits that afflict those children with ASD. reveal that atypical brain systems underpin several impairments in ASD, including verb processing difficulties, which may exacerbate the known deficits in social communication (83). Supporting evidence for atypical brain organization in individuals with ASD can also be found in studies from the language domain, which demonstrate atypical brain organization for linguistic processes in this population (84). Prior neurobiological research on infants, from which these expectations are derived, is frequently based on fMRI data (85). Yet it is only very recently that behavioural techniques have been used more extensively in the child language domain, with EEG being an attractive technique (86).

Taking an interdisciplinary approach through reviewing recent findings from dance movement therapy literature, which has the potential to reveal its efficacy and reliability in enhancing social-communication skills and language learning/ use in ASD (87). Affective mirroring and behavior matching, two of the central mechanisms underpinning the standard procedure of dance movement therapy, have long been linked to the MNS. predicted its application to the language domain (88). By addressing one of the grand empirical challenges identified by a novel methodology is proposed using electrophysiological measures of covert MNS activity. As the phenomenological and behavioral similarities between dance movements and some linguistic processes have been previously demonstrated, the neural translation of these retrieved content is explored (89). An increasingly rich and varied set of linguistic content is retrieved (90).

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