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Interpersonal Coordination in Schizophrenia: A Scoping Review of the Literature

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Interpersonal coordination forms the natural bridge between the self and others. It arises from the dynamic and complex set of embodied processes that involve nonverbal behaviors, perceptions, movement, and emotions that support adaptive interactions. Disembodiment has been implicated in a myriad of core clinical phenomena that manifest in a "praecox feeling" in persons with schizophrenia during interpersonal interactions. To further understand mechanisms underlying aberrant interpersonal interactions in schizophrenia, recent research has focused on mimicry, imitation, and interactional synchrony. In this study, we conducted a Pubmed, Web of Science, and PsycInfo database review of the literature on interpersonal coordination in schizophrenia to evaluate the body of work in mimicry, imitation, and interactional synchrony in relation to schizophrenia-spectrum conditions. The results of the review suggest that the sensory-motor processes underlying interpersonal coordination may result in impaired abilities to mimic and synchronize nonverbal behavior during interactions. Opportunities for future progress lie in studies of interpersonal coordination at different developmental stages of psychosis, potential use of interpersonal coordination to improve treatment adherence and reduce stigma, as well as interventions to improve social functioning in people with a serious mental illness.

Key words: scoping review/interpersonal coordination/mimicry/imitation/synchrony/nonverbal behavior/praecox feeling

Introduction

Interpersonal coordination forms a natural bridge from oneself to others, linking movement, sensation, emotion, and cognition between people. Take, for example, the experience of seeing people walk side-by-side, unconsciously adjusting their gait to fall into rhythmic strides. Picture an audience that naturally falls into clapping at the same rhythm at the end of a performance so that their applause sounds like 1 movement.[1] Consider rowers coordinating the stroke of the paddles and body movements to move a boat swiftly in the water or that football players will adjust their strides to pass a ball. So essential is interpersonal coordination that it is embedded implicitly without conscious awareness or effort in our daily interactions and is important for achieving interpersonal harmony. Given the effortless achievement of interpersonal coordination in daily life, the absence or loss of synchrony may cascade to social difficulties. Social disconnection and disrupted interpersonal coordination are common features of a wide range of neuropsychiatric conditions. Indeed, all forms of psychiatric disorders may be conceptualized as maladies of disrupted social homeostasis between the self and the social world. In the case of schizophrenia, the ineffable sense of impaired interpersonal coordination is captured by the concept of the "praecox feeling,"[2,3] which refers to the characteristic, subjective feeling of bizarreness experienced by the clinician when interacting with an individual diagnosed with schizophrenia. More recent conceptualizations of this phenomena subsumes interpersonal coordination into embodied cognition, illustrating the complex dynamics between the motor, temporal and spatial perception, and social cognition, which helps explain the myriad of social function impairments in schizophrenia.[4]

Interpersonal coordination may be divided into 2 interrelated categories: behavioral matching (ie, mimicry and imitation) and interactional synchrony (temporal dynamics of joint actions).[5] An important distinction is made between mimicry and imitation. Mimicry is associated with unconscious nonverbal behaviors such as facial expression in response to an emotional stimulus while imitation is an explicit process of copying the behavior of a stimulus, such as finger tapping along with a human hand. Social psychologists have noted that mimicry is associated with increased empathy, compassion, and monetary giving.[6,7] Implicit behavioral matching and coordination between the speaker and listener support the active listening component of turn taking, which promotes sharing of more personal information, improved rapport, and deepening of conversations.[8,9]

Traditionally, the Emotional Facial Action Coding System (EMFACS) has been used to investigate mimicry and nonverbal behavior in social activities.[10,11] More recently, electromyography (EMG) of facial movements has provided a more objective instrumental system by placing electrodes to measure the corrugator supercilii above the eye and the zygomaticus major along the chin measures facial muscles inversely related to frowning and smiling.[12] Imitation has been investigated using explicit processes of directing participants to smile or frown using arrows or verbal instruction while watching congruent and noncongruent emotional pictures, making an important distinction between implicit and explicit motor response to stimuli.[13] Automatic imitation paradigms often involve moving a hand or finger along with a stimulus.[14] Reaction times are shorter when participants are asked to make a congruent movement with the stimuli compared to incongruent movements to the stimuli and an important feature here is the ability to inhibit the natural response to imitate a movement.[15]

Interactional synchrony is a self-organizing dynamic process by which a person coordinates their behavior with the behavior of another person, requiring multiple processes of perception, simulation, cognition, anticipation, and motor behavior.[16,17] For example, dancing with a partner requires perception of the one's own body and another's body in space, a conceptual framework of how, where, and when to dance, specific knowledge of music and dance, anticipation of a partner's next dance move in space and time, and the coordination of one's own body.[18–20] Joint actions—behaviors performed with a partner toward a common goal—such as rowing, are also illustrative of how synchrony comes into play with interpersonal coordination.[21–23] Inside the laboratory, synchrony has been investigated in a number of ways. Early studies in this field have used ethological coding systems to describe interaction partners nonverbal behavior, noticing how bodies, limbs, and conversation synchronize over small units of time.[24] More recently, advances in video technology allow researchers to investigate gray-scale pixel density changes to capture motion energy using cross lagged correlation analysis of the movement time course between interactants.[25–28] Wrist pendulums, eg, weighted levers attached to a chair by a fulcrum where participants sit side-by-side (for details of experiment setup see [29]), are a gold standard measurement of joint action as they allow manipulation of leader-follower and intentional/unintentional synchrony.[30,31] Technological innovations over the past several years have aided our understanding of interactional synchrony.

Reviews of dyadic interactions with schizophrenia patients highlight a common finding that schizophrenia patients tend to move less, have restricted affect and show fewer gestures than healthy controls during social interactions.[24] Lavelle et al noted that patients with schizophrenia tend to show less nonverbal behavior during social interactions, negative and positive symptoms impact the amount of nonverbal behaviors, and greater symptomatology is associated with compensatory decrease in nonverbal behaviors with interacting partners. Del-Monte et al reviewed literature on social-motor coordination in schizophrenia and in social anxiety, highlighting shared features of interpersonal coordination across disorders.[32] In the time since these reviews, new innovations of technology to investigate interpersonal coordination, neuroimaging, and joint action mechanisms prompt a need for an update into this important literature. Previous studies have primarily focused on nonverbal behavior broadly using ethological coding systems or joint action, but they have not reviewed the literature with regard to interpersonal coordination from the perspective of mimicry, imitation, and interactional synchrony together. This review seeks to bring together the current body of literature on interpersonal coordination in people with schizophrenia and their relatives. The review will discuss the current body of evidence of behavioral matching and interactional synchrony in schizophrenia, highlighting the novel techniques and steps forward to continue understanding interpersonal coordination in this population. We acknowledge that a wide range of psychiatric conditions are associated with impaired interpersonal coordination including autism,[33,34] major depression,[35–37] social anxiety,[37] and borderline personality disorder.[38] However, we will limit the scope of this review to the schizophrenia-spectrum conditions while acknowledging the central role of interpersonal coordination across all psychiatric disorders.

Methods

The literature search involved keyword searches in Pubmed, Web of Science, and PyscInfo databases. Keyword searches included the terms "embodied synchronization," "interactional synchrony," "interpersonal coordination," "joint action," "movement synchrony," "mimicry," "imitation," "nonverbal synchrony," "social motor coordination," "social synchrony," "synchrony," and "schizophrenia." Title and abstract reviews were done in Rayyan Systematic Review software. Inclusion criteria included peer reviewed manuscripts, conference papers, and dissertations written in English. In cases where a publication closely matched the content of a dissertation, we chose the publication. There were no criteria for date of publication. We excluded papers on neuronal synchrony. In addition, we excluded papers that focused on illusions (ie, rubber hand illusion) and social Simon tasks as it was thought that these subjects were outside of the scope of interpersonal coordination and dealt with another important topic such as self/other discrimination and mentalizing.[39] We also used bibliographies of included papers to ensure we did not miss important literature during the initial internet search. Finally, we included studies from schizophrenia-spectrum samples including psychometrically ascertained schizotypal individuals and biological relatives of schizophrenia patients, as these groups inform our understanding of risk for schizophrenia.

Results

The literature search yielded a total of 1449 articles of which we included 35 papers in this review. The total sample size of schizophrenia patients was 921 (M = 26.8, SD = 14.37). The age of the schizophrenia patients across studies was 37.22 years (SD = 8.58) and the age of healthy control comparison participants was 34.57 years (SD = 10.41). Publication year ranged from 1980 to 2019. Of note, 3 papers included samples of unaffected relatives of schizophrenia patients and schizotypy[11,29,40]; These groups could be considered at high risk for psychosis. See Table 1 for details of included studies.

Mimicry

A total of 8 studies were included in this study for mimicry.[12,13,41–46] Comparisons between people with schizophrenia and healthy controls have been mixed, with 3 studies suggesting that schizophrenia patients and controls show similar abilities.[12,41,42] Other studies suggest that patients with schizophrenia may be slower to respond with facial mimicry during EMG recordings,[13] have a lower amplitude of expressivity in general,[43] have an altered pattern of corrugator and zygomaticus muscle movements throughout the time course of data collection,[44,46] and make greater errors in mimicry which are also associated with impaired ability to recognize mimicry from others.[45] The earliest studies on facial mimicry assessed facial expressions using EMFACS and qualitative analysis of patients observing emotionally provocative videos.[43,45] EMFACS coding studies suggest that schizophrenia patients show reduced facial mimicry of emotions compared to controls. Interestingly, in the same interaction, healthy controls showed a more rigid set of emotional expressions when interacting with schizophrenia patients compared with other controls suggesting that interactional partners may constrict their own affect with interacting with someone with schizophrenia patients.[43] Qualitative analysis of facial expressions of patients watching videos of interacting partners made more errors in recognizing mimicry and responded to emotionally valanced images with less mimicry.[45]

EMG studies present a more mixed picture of mimicry impairments in schizophrenia. Riehle and Lincoln did not find any group differences for smiling or frowning mimicry in EMG recordings during dyadic conversations between schizophrenia patients and healthy control interaction partners.[41] Better emotion recognition abilities were associated with better smiling mimicry. In another EMG study, Sestito et al found while emotion recognition was intact in schizophrenia patients, there was a differential effect of facial mimicry for positive and negatively valenced stimuli.[46] Specifically, schizophrenia patients failed to produce zygomaticus muscle activity during positively valenced stimuli but showed intact corrugator muscle activity during negatively valenced stimuli. In addition others have found that while schizophrenia patients show intact facial mimicry, response times are generally longer than healthy controls.[13] In contrast to these studies, Varcin et al noted that when schizophrenia patients viewed happy and angry facial expressions, the patterns of responding of corrugator and zygomaticus muscles showed an unusual pattern of responses throughout the course of viewing pictures, suggesting that the time course of facial mimicry may be impaired despite an overall intact performance.[44]

Imitation

A total of 17 studies were included for imitation in schizophrenia.[40,47–62] Some studies found impaired imitation across multiple different imitation tasks including movements of the fingers, mouth, and facial expressions.[61,71] However, Horan et al did not find imitation deficits for finger movements or facial expression in schizophrenia patients compared to healthy controls.[50] With respect to schizotypy, Butler et al[40] found no difference between high vs. low schizotypal college students. Simonsen et al showed enhanced automatic imitation and intact inhibition of incongruent imitation cues after controlling for cognitive and motor slowing using standard neuropsychological tests.[47] However, 2 other studies have noted that schizophrenia patients in general show slower reaction times and more errors during automatic imitation tasks.[49,59]

Studies of gesture imitation in schizophrenia suggest that 12%–23% of patients show impairment based on cutoff scores on the Test of Upper Limb Apraxia (TULIA).[53,56] The TULIA is a comprehensive measure of imitation and pantomime that includes tests of meaningless, symbolic, and tool-use gestures.[72] Matthews et al found that gesture imitation was impaired in schizophrenia patients when the imitative actions depended on working memory or multiple processes.[71] Walther et al have also found that impairment in imitation gestures was associated with nonverbal social perception and gesture knowledge.[55] Moreover, catatonia, neurological soft sings, and impaired cognitive abilities are associated with impaired imitation abilities.[56]

Patients with schizophrenia appear to be slower and less accurate in imitating facial expressions of different

Table 1. Summary of Included Studies (n = 35)

Citation	Sample	SZ Age (Mean or Range)	Control Age (Mean or Range)	Methods	Summary of Results	Medication Effect	Symptom Associations
Mimicry							
Riehle and Lincoln[41]	*N* = 28 SZ *N* = 28 HC *N* = 28 HC confederate	41.7 (10.7)	43.0 (12.1)	EMG	No group differences in mimicry.	None	Disorganized symptoms
Torregrossa et al[12]	*N* = 21 SZ *N* = 23 HC	47.90 (7.83)	45.65 (8.17)	EMG	Intact facial mimicry of emotions in SZ despite worse emotion recognition.	None	NA
Chechko et al[13]	*N* = 20 SZ *N* = 15 HC	38.04 (10.11)	39.81 (10.9)	EMG	SZ group was slower to respond with facial mimicry.	NA	None
Raffard et al[42]	*N* = 19 SZ *N* = 19 HC	31.9 (9.4)	30.5 (8.4)	Virtual reality avatar with motion tracking.	No group differences in mimicry. The mimicry condition produced greater rapport between avatar and participants.	None	None
Steimer-Krause et al[43]	*N* = 20 SZ *N* = 10 other psychopathology *N* = 50 HC	19–42	19–57	Observational study	SZ group showed lower facial expressivity although healthy controls also showed lower expressivity when interacting with schizophrenia patients compared to other clinical and nonclinical groups.	NA	NA
Varcin et al[44]	*N* = 25 SZ *N* = 25 HC	42.9 (9.43)	39.2 (10.85)	EMG	SZ group showed atypical pattern of corrugator and zygomaticus muscle activity revealing difficulty in facial mimicry.	None	None
Berndl et al[45]	*N* = 81 SZ *N* = 78 HC	35.9 (11.9)	40.3 (16.9)	Observational study	SZ group showed more errors in mimicry and had difficulty recognizing mimicry expressions in others.	None	None
Sestito, et al[46]	*N* = 15 SZ *N* = 15 HC	32.8 (1.69)	35.80 (2.28)	EMG	SZ group showed less zygomaticus muscle activity during positively valenced stimuli. No differences were found with negatively valenced stimuli.	NA	NA
Imitation							
Simonsen et al[47]	*N* = 33 SZ *N* = 40 HC	36.7 (10.1)	39.3 (10.5)	Automatic imitation	SZ group showed enhanced imitation compared to controls after controlling for cognitive, motor, and emotional processes	Imitation was positively correlated with higher medication dosage	None
Butler et al[40]	*N* = 20 high schizotypy *N* = 20 low schizotypy	-	21.62 (5.41)	Automatic imitation	No difference in automatic imitation between high and low schizotypy.	NA	None
Thakkar et al[48]	*N* = 16 SZ *N* = 16 HC	40.2 (9.1)	37.4 (7.0)	Automatic imitation, fMRI	SZ group showed lower activation in the mirror neuron system during imitative vs nonimitative action.	Higher dosage of medication were associated with more normal mirror neuron system activation	NA
Dankinas et al[49]	*N* = 14 SZ *N* = 15 HC	37.1 (13.9)	39.9 (13.5)	Automatic imitation	SZ group were slower in responding to imitative and counter-imitative finger press compared to controls	None	NA
Horan et al[50]	*N* = 23 SZ *N* = 23 HC	46.5 (11.1)	46.7 (6.9)	Automatic imitation, fMRI	No group differences in brain activation for imitation of finger or facial movement.	None	Negative symptoms
Matthews et al[51]	*N* = 14 SZ *N* = 14 HC	40.2 (8.6)	40.0 (10.2)	Automatic imitation	Gesture imitation was impaired in SZ group when imitation depended upon working memory and multiple actions.	None	Negative symptoms

Table 1. Continued

Citation	Sample	SZ Age (Mean or Range)	Control Age (Mean or Range)	Methods	Summary of Results	Medication Effect	Symptom Associations
Stegmayer et al[52]	*N* = 45 SZ *N* = 44 HC	38.24 (11.37)	38.77 (13.58)	Test of Upper Limb Apraxia, Voxel based morphometry	SZ group performed worse across imitation and pantomime domains. 13% of patients showed deficits below recommended cutoff for imitation. Pantomime deficits were associated with decreased gray matter in hippocampus, insula, parietal cortex, and superior temporal gyrus.	None	NA
Stegmayer et al[53]	*N* = 14 FEP SZ *N* = 14 chronic SZ *N* = 16 HC	27.2 (8.5)	28.1 (4.6)	Test of Upper Limb Apraxia	Imitation abilities were lowest in chronic SZ. FEP patients were worse than healthy controls.	None	NA
Viher et al[54]	*N* = 40 SZ *N* = 41 HC	38.61 (9.24)	38.93 (13.69)	Test of Upper Limb Apraxia, cortical thickness	SZ group with gesture deficits showed reduced cortical thickness in inferior parietal cortex, middle temporal gyrus, inferior frontal gyrus, primary motor, superior parietal cortex, supramarginal gyrus, and insula compared to healthy controls.	None	None
Walther et al[55]	*N* = 46 SZ *N* = 44 HC	37.96 (11.17)	38.77 (13.58)	Test of Upper Limb Apraxia, Tool Use Test, Postural Knowledge task, Test of Nonverbal Intelligence	SZ group showed uniform impaired nonverbal communication across all 4 tasks. Within the SZ group, gesture performance was associated with nonverbal social perception, gesture knowledge and tool use. Motor and cognitive abilities were associated with impaired nonverbal communication. Motor and cognitive abilities partially mediated the association between nonverbal perception and gesture performance.	None	Positive symptoms inversely correlated with nonverbal social perception/gesture performance
Walther et al[56]	*N* = 30 SZ	41.1 (11.95)	-	Test of Upper Limb Apraxia	SZ group was uniformly impaired on both imitative and pantomime gestures. In pantomime gestures, patients were more impaired when performing meaningless gestures. Pantomimed meaningless gestures were correlated with the Frontal Assessment Battery	Gestural deficits correlate with high antipsychotic medication dosage.	NA
Walther et al[57]	*N* = 30 SZ *N* = 30 HC	40.2 (-)	42.2 (-)	Test of Upper Limb Apraxia	40% of SZ group showed gesture impairment during pantomime and 23% showed impairment with imitation. Impaired pantomime was associated with frontal lobe function. Imitation was associated with catatonia and wrist actigraphy.	Gestural deficits correlate with high antipsychotic medication dosage.	Negative symptoms
Lee et al[58]	*N* = 15 SZ *N* = 16 HC	36.7 (8.1)	36.8 (6.3)	Facial expression imitation, fMRI	SZ group was less expressive for both happiness and sadness than healthy controls. However, poor expressiveness did not result from deficits in emotional recognition. Also, there were increased irrelevant responses when faced with facial/word expressions.	None	Negative symptoms

Table 1. Continued

Citation	Sample	SZ Age (Mean or Range)	Control Age (Mean or Range)	Methods	Summary of Results	Medication Effect	Symptom Associations
Falkenberg et al[59]	N = 17 SZ N = 17 HC	28.2 (7.4)	27.6 (5.4)	Facial expression imitation, EMG	Reaction times were slower in SZ group. SZ group tended to show more incongruence between their increased smiling and negatively valenced facial pictures.	NA	Total symptoms
Mazza et al[60]	N = 32 SZ	24.45 (2.14)	-	Emotion and ToM Imitation Training (ETIT)	Social cognition improved following ETIT.	NA	NA
Park et al[61]	N = 20 SZ N = 16 HC	38.6 (10.3)	37.9 (8.6)	Imitation of hand and facial features	SZ group showed less accurate imitation than healthy controls.	NA	Total BPRS and negative symptoms
Schwartz et al[62]	N = 20 SZ N = 10 HC	46.2 (10.9)	12.9 (1.9)	Facial imitation of expressed emotion	SZ group was less accurate at imitating facial expressions than healthy controls.	Medication dose was positively associated with impaired imitation of disgust	NA
Interpersonal synchrony							
Słowiński et al[63]	Study 1: N = 30 SZ, N = 29 HC. Study 2: N = 22 SZ, N = 22 HC	18–58	19–49	Mirror game with iCub Robot	Majority rule classification found that features of synchronized motor activity with computer avatar and iCub robot could be used to predict schizophrenia with 93% accuracy and 100% specificity.	None	NA
Raffard et al[64]	N = 45 SZ N = 45 HC N = 90 SZ	18–61	18–56	Joint action task using a wrist pendulum	When given a pro-social priming prior to pendulum task, SZ group showed greater stability of synchronization. Pro-social priming increased stability of synchronization. Increased synchronization was related to more interpersonal rapport between schizophrenia and healthy comparison subjects.	NA	None
Kupper et al[65]	N = 27 SZ	-	-	Motion energy analysis	Lower synchrony was associated with the severity of symptoms, social cognition and functioning, self-esteem.	NA	Negative symptoms were inversely associated with imitation of patients towards their partner. Positive symptoms were associated with worse imitation from interactional partners.
Del-Monte et al[29]	N = 27 relatives N = 27 HC N = 54 HC confederate	61.37 (6.48)	59.74 (6.99)	Joint action task using a wrist pendulum	Relatives of SZ patients showed less coordination during intentional motor synchronization.	NA	None
Cohen et al[66]	N = 22 SZ N = 22 HC	21–45	19–46	Synchronized arm movements with an iCub robot	SZ group showed lower overall synchrony with the robot. Social feedback did not have a facilitatory effect on synchrony.	Antipsychotic medication had an impeding effect on synchrony.	Negative symptoms

Table 1. Continued

Citation	Sample	SZ Age (Mean or Range)	Control Age (Mean or Range)	Methods	Summary of Results	Medication Effect	Symptom Associations
Lavelle et al[67]	N = 20 SZ N =100 HC	41.50 (8.64)	31.10 (9.60)	Video motion capture during a 3-person interaction	SZ group speak less and gesture less. More gestures made by patients was associated with less rapport.	Coordination between participants inversely correlated with antipsychotic medication.	Negative symptoms were associated with less nodding and more gestures when speaking. Patients with more positive symptoms nodded more when listening. Patients' partners displayed less listener nodding when patients were more symptomatic.
Varlet et al[68]	N = 20 SZ 2 separate (N = 20) HC groups	38.15 (10.19)	35.60 (14.74)	Joint action task using a wrist pendulum	Intentional coordination is impaired in schizophrenia. Unintentional coordination remains intact.	None	None
Galbusera et al[69]	N = 16 SZ	42 (12.7)	-	Motion energy analysis	Interactional synchrony improved following therapy.	NA	Negative symptoms
Ellgring et al[11]	N = 10 SZ	17–46	-	Facial Action Coding System (FACS), gesture, nonverbal behavior, gaze and speech patterns between interactional partners	Both relatives and schizophrenia patients showed lower than expected facial expressivity in speaker roles.	NA	NA
Hardin et al[70]	N = 6 SZ N = 6 HC	20–35	-	Observational study	HC-HC and HC-SZ showed ability to synchronize legs but SZ-SZ dyads did show any synchronization. Oscillations were only observed in SZ-SZ dyads. Dyads involving SZ showed more imitation behaviors.	NA	NA

Note: A Pubmed, Web of Science, and Psychinfo database search was performed for studies involving interpersonal coordination and separated into 3 domains: mimicry, imitation, and interactional synchrony. EMG, electromyography; HC, healthy controls; NA, not assessed; None, no association; SZ, patients with schizophrenia. Age range or mean (SD) for patient and comparison groups is provided when possible. A (-) denotes data that are not available.

emotions such as happiness, sadness, anger, and disgust[61,62] after accounting for impaired emotion recognition.[58] Falkenberg et al observed that schizophrenia patients often made incongruent smiling features while observing negatively valenced pictures of faces.[59]

An important contribution of the imitation literature are investigations of neural correlates, creating links between behavioral paradigms and social neuroscience. Not surprisingly, imitation is associated with brain networks that involve motor performance, the mirror neuron network, theory of mind, and social cognitive domains such as empathy. Thakkar et al investigated mirror neuron network activation and found reduced activation in the right posterior superior temporal sulcus during imitative actions in schizophrenia patients compared to healthy controls.[48] Horan et al found that schizophrenia patients showed a similar pattern of activation as controls during imitative actions, with greater activation in visual, frontal, parietal, and basal ganglia regions compared to execute and observation tasks across both groups.[50] Stegmayer et al investigated gray matter correlates of gestures and found significant clusters in the inferior frontal gyrus, right insula, and anterior cingulate, where worse gesture performance was associated with greater gray matter reduction. In a separate study by the same research group, Viher et al showed that schizophrenia patients had reduced gray matter thickness in cortical regions such as inferior parietal cortex, middle temporal cortex, superior parietal cortex, supramarginal gyrus, and insula associated with impaired gesture performance.[54]

Here, we must note the relevance of the mirror neuron literature in all studies of imitation since some but not all forms of mirror matching mechanism is thought to underlie our ability to imitate other people's behavior.[73] For a review of the mirror neuron mechanisms in schizophrenia please refer to Mehta et al.[74]

Interactional Synchrony

There were a total of 10 studies on interactional synchrony.[11,29,63–70] In contrast to the mixed results of mimicry and imitation, studies of interpersonal synchrony suggest that patients with schizophrenia are impaired across modalities, and the various tools provide nuance to this domain.

Observational coding of synchronous movements during interpersonal interactions in patients with schizophrenia, their relatives, and healthy comparison subjects suggest that both relatives and patients show less facial movements during speaking roles.[11] Oscillatory body movements (eg, rocking forward or backward, nodding the head up and down) during conversation convey engagement and when speaking to nonclinical partners or other patients with schizophrenia alike, patients with schizophrenia show less synchronous behavior. The authors suggest that this behavior is a part of an approach-avoidance behavior that inhibits patients with schizophrenia from naturally forming personal relationships with others.

Joint action paradigms utilizing wrist pendulums have shown that in comparison to a healthy control group, first-degree relatives of patients with schizophrenia show less motor synchrony when explicitly tasked with coordinating their movement with a partner than without explicit directions. These results held despite controlling for scores on neurological soft signs and cognitive tests.[29] The authors hypothesized that the perceptual skills of the relatives, visual tracking acuity, and impaired temporal processing may partially explain these results. The finding of impaired intentional synchrony in relatives was repeated in a sample of patients with schizophrenia,[68] suggesting that impaired interpersonal synchrony may be an endophenotype for schizophrenia. Interestingly, other studies suggest that pro-social priming prior to a wrist pendulum task increases interpersonally synchrony between patients with schizophrenia and healthy controls, and interactional synchrony improves rapport between participants, suggesting a possible mechanism to improve patient relationships with others.[64]

Virtual avatars and robots have made inroads in studies that investigate social-motor synchrony. These robots are programmed to perform sequences of movements and track the patient's movements at the same time, providing high quality continuous data. The iCub robot in particular have been used in 2 studies of interpersonal synchrony. In 1 study, interpersonal synchronous movements (ie, following the motion of a target or movement of the robot) were used as predictors in a machine learning algorithm to classify participants as either healthy controls or patients with schizophrenia with 93% accuracy and 100% specificity.[63] In another study, the robot was programmed to follow movements and give socially relevant feedback to participants depending on their ability to move synchronously with the robot (ie, the interface showed a smile when a participant was able to synchronize their movements). Overall, patients with schizophrenia showed less overall synchrony and responded less to feedback to adjust their movements compared to healthy controls.

Video motion capture systems, such as motion energy analysis, have been utilized in several studies of interactional synchrony. In a sample of patients with schizophrenia performing roleplays of social interactions with a study confederate, Kupper et al found that less synchrony was associated with the severity of negative symptoms, cognition, and general functioning.[65] In a 3-person interaction, where 1 schizophrenia patient sat in between 2 healthy comparison participants in a semi-circle while discussing a moral dilemma, schizophrenia patients tend to speak less and gesture less, although the response to patients was interesting in that healthy control listeners tended to nod less and show less reciprocal synchronization with patients, especially when patients were more symptomatic.[67] However, healthy control listening partners also appeared to engage in more nonverbal behaviors while schizophrenia patients spoke, perhaps to compensate for less gestures by patients. In an innovative study utilizing a body-oriented therapy, schizophrenia patients showed statistically significant improvement in interactional synchrony during clinical interviews following therapy, suggesting that synchrony may be learned through enhanced body awareness.[69]

Effect of Medication

Five out of 7 studies in mimicry assessed the contribution of antipsychotic medication to mimicry and none of the studies noted a significant association or that antipsychotic medication impacted the results.

The effect of medication on imitation was heterogeneous. Simonsen et al found that a greater medication dose was associated with improved imitation.[47] Thakkar et al found that antipsychotic medication appeared to enhance fMRI brain activation in posterior superior temporal gyrus regions during imitation tasks in patients with schizophrenia, suggesting that for patients on higher dosages, their brain activity in the mirror neuron network were more similar to controls.[48] Walther et al found that high antipsychotic medication dosages were associated with worse gesture performance.[56,57] Schwartz et al found that higher antipsychotic medication dosage was associated with a specific impaired ability to imitate disgust but not associated with other emotions.[62] In 11 of the studies included, no association with antipsychotic medications were found or were not assessed.

With regard to synchrony, 2 studies found that higher dosages of antipsychotic medication impeded synchrony of facial features with the iCub robot[66] and did not help facilitate coordination in schizophrenia during a 3-person interaction.[67]

Lastly, we note that interpersonal coordination difficulties are also observed in unaffected relatives with schizophrenia in the absence of antipsychotic medication.[29]

Correlates With Symptoms

Few studies in mimicry have found correlations with schizophrenia symptom domains. In Riehle and Lincoln, the study found that a subcomponent of negative symptoms, reduce facial expressivity, was inversely correlated with mimicry in the schizophrenia patient group.[41]

Given connections among emotion, affect, cognition, and motor slowing, it is not surprising to find that associations with negative symptoms are most consistently found with imitation activities. Matthews et al found that the severity of negative symptoms was associated with the temporal and spatial components of gesture imitation.[71] Similarly, the severity of negative symptoms is associated with impaired gesture performance, impaired facial expressivity,[59] and accuracy of imitation.[61]

In studies of interactional synchrony, negative symptoms were inversely correlated with a patient's ability to synchronize their movement with their interaction partner in several studies.[65,66,69] Interestingly, positive symptoms were correlated with an inability of a healthy control participant to synchronize their movements with the patient and fewer nonverbal behaviors to indicate that the healthy interaction partners were listening to a conversation.[65,67]

Discussion

This review provides a scope of the current literature on interpersonal coordination in schizophrenia across 3 categories: mimicry, imitation, and interactional synchrony. Studies in mimicry suggest that patients with schizophrenia show less and more variable facial features during interactions. Imitation results are somewhat mixed with some studies showing deficits in schizophrenia patients and others showing intact imitation. Studies in imitation also highlight important brain networks that contribute to social-motor impairment in schizophrenia including altered activation and volume of gray matter in inferior frontal, superior temporal cortex, insula, and cortical/subcortical motor brain regions. Studies investigating interactional synchrony may hold promise as an endophenotype for schizophrenia and suggest that dynamic patterns of interpersonal behavior are altered between patients with schizophrenia and healthy controls. Antipsychotic medications appear to ameliorate both core positive symptomatology, mirror neuron network function, and behaviors that impact interpersonal coordination in patients with schizophrenia. While negative symptoms, such as affective flattening, appear to most closely related to components of interpersonal coordination, positive symptoms impact other people's perception of patients with schizophrenia resulting in impaired synchrony and coordination. These results highlight the complex social behavior exhibited and encountered by people with schizophrenia and others in the world. This body of work suggests that the dynamic processes that underly complex social interactions, namely sensory-motor processing and cognition, may be responsible for impaired interpersonal coordination in schizophrenia.

What mechanisms might underlie difficulties with interpersonal coordination? Impairments of mimicry, imitation, and interpersonal synchrony share certain common features. First, there might be problems at the perceptual input stage during social interactions. For example, sensory, perceptual, or attentional difficulties during the input stage means the participant does not perceive the other person's behavior and therefore, interpersonal coordination does not occur. It is also possible that lapses of attention or misperception led to incorrect encoding of the other person's behavior, which can then result in incorrect mimicry, imitation, or loss of synchrony. Second, there might be problems at the output or production stage. Even if the participant correctly perceived and attended to the other person's behavior (ie, intact processing at the input stage), there might be difficulties at the output stage (ie, production of behavior). This could be due to motor deficits including gesture production difficulties. This could also be the result of severe amotivation. On the other hand, it is possible that the participant is motivated and produces social behavior in response to the other person's actions, but that the output is incorrect or poorly timed. In this case, deficient execution of the motor sequence or behavior would be responsible for poor interpersonal coordination. Third, we must consider a broader social context. For example, paranoia could heighten one's attention to social cues. However, increased attention to social cues may not help with the production of appropriate coordinated behavior if there are existing motor production deficits. Accurate perception but difficulties with production and therefore loss of synchrony could lead to disrupted social interactions, and perhaps further exacerbate paranoia. Fourth, schizophrenia is associated with abnormal timing and time perception.[75,76] Given the importance of timing in interpersonal coordination, we must consider the contribution of time perception difficulties in schizophrenia. But the current literature on mimicry, imitation, and interpersonal synchrony does not address the timing issue. These, and other factors may give rise to abnormal mimicry, imitation, or interpersonal synchrony.

Phenomenologists have posited that a core feature of schizophrenia is disembodiment characterized by impaired automaticity of sensory-motor processes (ie, knowledge of the self in the world) and tacit knowledge of how to be with others (ie, common sense of how to interact with others).[4,77,78] Sensory-motor processes have been shown to be impaired early in life in people who later develop schizophrenia and may represent a marker for increases risk for psychosis.[79–83] Social functioning is also an early marker of risk for schizophrenia although social skill training can improve in people with schizophrenia, suggesting that interventions teaching patients with schizophrenia basic knowledge of how to interact with others have positive benefits for schizophrenia symptoms.[84,85] Research on interpersonal coordination supports theories of disembodiment in schizophrenia, as the components of interpersonal coordination rely on both implicit sensory-motor processes (ie, mimicry and interactional synchrony) and tacit knowledge of nonverbal behaviors that support interpersonal coordination (ie, imitation). Our results suggest that impairments in interpersonal coordination in patients with schizophrenia are found mostly in domains affecting implicit sensory-motor abilities. This is consistent with a mass of literature that suggests that sensory perception is altered in schizophrenia on basic levels such as the structure of the retina as well as basic processes of motor performance and development.[86–88]

During an intentional joint action paradigm, relatives of patients with schizophrenia show an impaired ability to synchronize their movements with an interaction partners, similar to patients.[29] Observational studies also note that people with schizophrenia have difficulty synchronizing their body movements with their relatives.[11] These findings suggests that impaired interactional synchrony may be an endophenotype for schizophrenia. The only other study included in this review to study interpersonal coordination in subjects at risk for psychosis showed no differences in imitation abilities between college students who scored high and low on a measure of schizotypy.[40] Interestingly, even in healthy, nonclinical samples, smiling mimicry, and facial expressivity are modestly correlated with dyadic interaction partners willingness to engage in social interactions, suggesting that subthreshold correlates of negative symptoms are associated with social functioning and may be important for supporting efforts to build social networks.[89] Further research on interpersonal coordination in people with indications of risk for psychosis would help improve our understanding of how these processes develop, whether they are associated with neurodevelopmental indicators of psychosis, and if they can help improve early identification and prevention efforts.

Of the studies included in this review, 2 studies used interpersonal coordination as a measure of intervention outcome. Galbusera et al used motion energy analysis to investigate changes in body movement synchrony before and after a body-oriented psychotherapy.[69] Schizophrenia patients showed improved synchrony and negative symptoms following therapy, suggesting that targeting basic sensory-motor disturbance in psychotherapy can improve synchrony. In addition, Mazza et al used an emotion and theory of mind imitation intervention that showed improved social cognition as well as increased medial/frontal brain activity in schizophrenia patients compared to a clinical group who only received a problem-solving intervention.[60] This suggests that imitation could be useful for training interpersonal coordination in patients with schizophrenia.

Much of the research on sensory-motor abnormalities focus on patients with schizophrenia relative to healthy controls, however, the studies included in this paper provide a window into the dynamics of interactions between both interaction partners. It is important to recognize that healthy controls also show decreased synchrony while interacting with patients with schizophrenia, possibly in response to positive, negative, or disorganized symptoms. This brings attention to the implicit and explicit stigma attached to mental illness.[90,91] The good news is that social and developmental psychologists have noted that interpersonal coordination increases rapport between people, allows parents to bond with offspring, and elicits feelings of empathy and compassion from others.[92–96] In the context of therapeutic relationships between psychotherapy patients and providers, interpersonal coordination is associated with greater rapport and perceived progress in therapy.[28,97] Paying attention to nonverbal behavior and using imitation, and mimicry, and interactional synchrony may be an impactful way of creating stronger client-therapist rapport, and future research could examine how these interpersonal coordination tools may be used to improve medication adherence, commitment to therapy, and recovery in people with schizophrenia.

There are caveats. We focused narrowly on 3 aspects of interpersonal coordination: mimicry, imitation, and interactional synchrony. Therefore, many related constructs such as the mirror mechanisms, action observation and empathy lie beyond the scope of this review. Nevertheless, it seems clear that the ability to match or coordinate one's own behavior to another person's is compromised in individuals with schizophrenia. Further research is needed to elucidate the neural and sensory-motor origins of social discoordination in schizophrenia in order to develop effective behavioral intervention strategies that target social skills for a better functional outcome in this population.

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