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Produced and perceived interpersonal synchrony, social affiliation, and affect in dyadic interactions of individuals with and without Autism Spectrum Disorder

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Nanja Teresa Scheel

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Erstes Gutachten:	Prof. Dr. Christine Falter-Wagner
Zweites Gutachten:	Prof. Dr. Thomas Geyer
Drittes Gutachten:	Prof. Dr. Inga Katharina Koerte

Mitbetreuung durch den promovierten Mitarbeiter:	
Dekan:	Prof. Dr. med. Thomas Gudermann
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ABSTRACT

Individuals with Autism Spectrum Disorder (ASD) exhibit communication and interaction difficulties, often severely impacting their quality of life. A fundamental and contextual understanding of the underlying mechanisms is essential to enable targeted interventions for individuals with ASD. Interpersonal Synchrony (IPS) has been found to influence various aspects of social interactions and is altered in ASD (McNaughton & Redcay, 2020). This study aimed to scrutinize IPS, synchrony perception, social affiliation, and affect as fundamental aspects of social interactions for individuals with ASD and typically developed (TD) individuals. All participants (n_{ASD} = 24, n_{TD} = 28) engaged in a *conversational task* with previously unacquainted confederates. The dyadic conversations were video recorded to analyze IPS from each dyad using Motion Energy Analysis (MEA; Ramseyer & Tschacher, 2011). Questionnaires assessed positive affect, social affiliation, and perceived synchrony. Descriptive statistics and linear mixed-effects models were employed to dissect the variables of interest IPS, social affiliation, positive affect change, and perceived synchrony. This study captured a difference in reported synchrony perception between the groups, illustrating altered synchrony processing in ASD. In line with previous research, reduced IPS in the ASD group was found in a subtask of the naturalistic conversation. The findings did not provide evidence that IPS or the diagnostic group significantly influenced social affiliation in this sample. However, IPS modulated positive affect differently in the diagnostic groups. The data suggested less positive affect change in the ASD group throughout the conversation. In conclusion, this study reveals substantial differences in synchrony production, perception, and emotional aspects throughout a conversation, while showing no evidence of differences in social affiliation. As such, the study provides novel insight into essential aspects of perceptual and behavioral patterns during social interactions in individuals with ASD.

ZUSAMMENFASSUNG

Menschen mit Autismus-Spektrum-Störung (ASS) erleben vermehrt Schwierigkeiten in Kommunikation und Interaktion, die das tägliche Leben beträchtlich beeinflussen können. Als ein daran beteiligter Mechanismus gilt die interpersonelle Synchronie (IPS). Trotz dokumentierter Veränderungen im interaktiven Bereich wurde der Einfluss eines dyadischen Gesprächs und der IPS auf den Affekt und die soziale Bindung bei Erwachsenen mit ASS noch nicht im Speziellen erforscht. Um ein umfassenderes Verständnis über Wahrnehmungs- und Verhaltensmuster zu erzielen ist es von erheblicher Relevanz, diese Parameter bei Personen mit ASS (n = 24) im Vergleich zu neurotypischen Personen (NT; n = 28) näher zu untersuchen. Alle Probanden und Probandinnen nahmen an einer dyadischen Gesprächsaufgabe teil. Hiervon wurden Videoaufnahmen angefertigt, um mithilfe von Motion Energy Analysis (MEA) die IPS der jeweiligen Dyaden zu quantifizieren. Der positive Affekt, die soziale Bindung und die Wahrnehmung der Synchronie wurden mittels Fragebögen erhoben. Beschreibende Statistik und gemischte Modelle wurden angewandt, um den Zusammenhang zwischen den Variablen zu analysieren. Diese Studie erfasst Abweichungen in der Wahrnehmung von Synchronie in der ASS Gruppe, woraus sich eine veränderte Verarbeitung von Synchronie schlussfolgern lässt. Ergebnisse weisen zudem auf reduzierte IPS in der ASS Gruppe und auf ein ähnliches Ausmaß an sozialer Bindung in beiden Gruppen hin. Für einen signifikanten Einfluss von IPS auf die soziale Bindung gibt es in dieser Stichprobe keine Evidenz; stattdessen verdeutlichen die Resultate, dass IPS den Affekt auf unterschiedliche Weise in den beiden Gruppen moduliert. Zusammenfassend zeigt diese Studie essenzielle Unterschiede in der Synchronie-Wahrnehmung, der Synchronie-Produktion und in emotionalen Aspekten, verdeutlicht Ähnlichkeiten in sozialem Bindungsverhalten und bietet umfassende Einblicke in nonverbale Verhaltensmuster, Empfindungen und die Wahrnehmung von Menschen mit ASS.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

General

- LMU Ludwig-Maximilians-Universität
- NEVIA Neurodevelopmental Disorders and Interaction

Medical/ Psychological Terms

- ASD Autism Spectrum Disorder
- TD Typically Developed
- SAD Social Anxiety Disorder
- fMRI Functional Magnetic Resonance Imaging
- ICD International Classification of Diseases
- COVID-19 Coronavirus Disease 2019
- ToM Theory of Mind
- IQ Intelligence Quotient

Questionnaires

- CFT 20-R Cultural Fair Intelligence Test- 20- revised (Weiß, 2006)
- MWT-B Mehrfachwahl-Wortschatz-Intelligenztest (Lehrl et al., 1999)
- AQ Autism Quotient (Baron-Cohen et al., 2001)
- SPF Saarbrücker Persönlichkeitsfragebogen (Paulus, 2009)
- ADC Adult Dyspraxia Checklist (Kirby et al., 2010)

Video analysis

- MEA Motion Energy Analysis (Ramseyer & Tschacher, 2011)
- ROI Region(s) Of Interest
- IPS Interpersonal Synchrony
- MQ Movement Quantity

Statistical Terms

- LME Linear Mixed-Effects Model

1. INTRODUCTION

1.1 AUTISM SPECTRUM DISORDER

1.1.1 COMMUNICATION AND INTERACTION

Autism Spectrum Disorder[1] (ASD) is classified as a neurodevelopmental disorder and, among other traits, is characterized by impaired communication in social interaction domains (World Health Organization [WHO], 1993). ASD is an umbrella term for various individual manifestations, mandatorily including pervasive impairment in the domains of communication and interaction, repetitive behavior, and specific interests (AWMF, 2016). While the prevalence of ASD differs across studies and countries, it is suspected that around 1% of the population is affected (AWMF, 2016). ASD is characterized by interaction, communication, and social perception difficulties that occur predominantly in the nonverbal domain (Thaler et al., 2021). These differences in interactive patterns appear at a young age, and the condition remains for life. A variety of communication patterns are pervasively different in individuals with ASD, such as initiating conversations, providing content of mutual interest for the conversational partner, and engaging in reciprocal exchanges (Paul et al., 2009).

Atypical communication and nonverbal signaling in ASD manifests, for example, in the characteristic unconscious avoidance of eye gaze (Madipakkam et al., 2017; Paul et al., 2009). Eye gaze is considered an essential component of social interactions and

[1] It is widely debated how to respectfully address people on the Autism Spectrum and which vocabulary to use when referring to Autism. Individual preferences vary across the community (Kenny et al., 2016). To date, the Diagnostic and Statistical Manual of Mental Disorders (DSM-5; American Psychiatric Association, 2013) uses the term Autism Spectrum Disorder (ASD) to describe the official diagnosis behind a symptom cluster mainly comprised of interaction and communication difficulties as well as restrictive and repetitive behavioral patterns. In this thesis, the expression “participants or individuals with ASD” is used, given that the participants for this study had received an official ASD diagnosis before participation. This term is not meant to stigmatize or offend any person but used as a descriptive term for the collective assessed in this study.

plays a massive role in communicative signaling, often affecting psychiatric disorders (Emery, 2000). A prospective longitudinal study revealed that infants who later received a diagnosis of ASD showed a decline in eye contact in the first two to six months of life (Jones & Klin, 2013). In a study using functional magnetic resonance imaging (fMRI), participants observed faces of virtual figures with averted or direct eye gaze, differing in duration (Georgescu et al., 2013). Interestingly, participants with ASD, in contrast to control participants, did not rate the virtual characters as more likable when eye gaze duration increased. Moreover, the neuroimaging results indicated that participants with ASD did not process direct eye gaze social information.

Facial expressions are also considered necessary for the social cognition of nonverbal behavior and are essential to indicate one's feelings of involvement (Schwartz et al., 2010). Schwartz et al. (2010) demonstrated that eye gaze directionality and facial expressions had less influence on feelings of involvement in participants with ASD during an engagement with a virtual character that simulated different conditions of nonverbal behavior. Processing facial expressions and adequately reading the linked emotions are essential for nonverbal communication and are reportedly different in individuals with ASD. Baron-Cohen developed the *theory-of-mind* (ToM) hypothesis of ASD, also referred to as *mind blindness,* which considers one´s ability to attribute mental states to oneself and others correctly (Baron-Cohen, 1995; Baron-Cohen et al., 1985). Since the ToM account has become influential, a vast body of literature has investigated this matter showing mentalizing differences in ASD (Bruning et al., 2005; David et al., 2008). Individuals with ASD tend to show reduced attribution of mental states to others (Hill et al., 2004).

Given that interactions are at least two-sided, the *double empathy problem* (Milton, 2012) accounts for understanding issues from not only one interaction partner but two. It refers to the communication gap between individuals with ASD and TD individuals. On the one hand, individuals with ASD tend to show differences in recognizing nonverbal communication cues and difficulties in emotion comprehension (Mathersul et al., 2013; Uljarevic & Hamilton, 2013). On the other hand, Alkhalid et al. (2019) and Sheppard et al. (2016) demonstrated that TD participants have difficulties relating to and comprehending the behaviors and cognitive processes of participants with ASD. Readability of these inner processes correlated with ratings of the person's favorability. Individuals with ASD tend to be rated by their conversational partners as more awkward and less socially warm than TD individuals after a naturalistic social interaction (Morrison et al., 2019). In addition, TD observers rated participants with ASD as less favorable than TD participants by first impression (Sasson & Morrison, 2019).

1.1.2 AFFECT

Aside from altered nonverbal characteristics, individuals with ASD show differences in affective states compared with TD individuals. For example, socially meaningful facial expressions from virtual characters had less influence on the overall feelings of participants with ASD than TD participants (Schwartz et al., 2010). Additionally, facial expressions did not impact the urge to establish contact with the virtual partners in participants with ASD. One phenomenon that may also be prevalent in ASD is the impairment in emotion processing, such as identifying and describing feelings (Hill et al., 2004). In this context, the *alexithymia* construct, or *emotional blindness* (Sifneos, 1973), refers to difficulties in adequately reading emotions and may underly practical problems in emotional processing in ASD. Bloch et al. (2021) found that autistic traits significantly correlated with depressive symptoms. Still, *alexithymia* traits were stronger predictors for depressive symptoms and co-occurred with ASD. This finding aligns with Hill et al. (2004), who found great difficulties in cognitive emotion processing related to depression in individuals with ASD. A systematic review and meta-analysis revealed that mental health comorbidities among adults with ASD were highly present, given the lifetime prevalence of any anxiety disorder at 42% and depressive disorder at 37% (Hollocks et al., 2019). In individuals with ASD, social anxiety symptoms are increased and similar to patients with a social anxiety disorder (SAD) but, in contrast to the SAD group, likely arise from social competence difficulties and social retreat (Espeloer et al., 2021).

1.1.3 SOCIAL AFFILIATION

Aside from divergence in emotional mechanisms in individuals with ASD, evidence suggests that social bonding works differently. Since social engagement is considered an essential component in naturalistic and virtual interactions, individuals with ASD exhibit reduced interest in engaging in social interactions (Schwartz et al., 2010). The *Cyberball* paradigm investigates behavior after experiencing or witnessing social exclusion. Participants play a virtual ball game with other players, who are, in fact, computer-generated players, and one of the players is excluded from the game (Williams et al., 2000). Using the *Cyberball* paradigm, Silva et al. (2019) assessed behavior within ASD and TD participants after witnessing someone being excluded from the game. Even though both diagnostic groups were aware of the social rejection, only TD participants reacted with a change in behavior and state of mind. The TD participants played significantly more with the previously ostracized player and less with the excluding player compared to the participants with ASD. Additionally, positive affect (more precisely, scores from the joy subscale) declined more for the TD participants, indicating that participants with ASD seem to process social exclusion differently or at least emotionally react in an altered manner. Another study monitored body reactions, such as the autonomous nervous system, during naturalistic dyadic[2] social interactions

[2] Dyadic interaction refers to social engagement between two people.

(Stevanovic et al., 2019). The experiments demonstrated specific differences between the ASD and TD groups in emotional and physiological responses during social interactions[3]. Morrison et al. (2019) investigated the influence of an unstructured conversation between three different dyad types (ASD-ASD, TD-TD, ASD-TD) on the interaction quality and the conversational partner's impression. TD participants preferred potential future interactions rather with a TD interaction partner compared to an ASD interaction partner. In contrast, ASD participants were more interested in interacting with other ASD participants in the future. Surprisingly, ASD participants, compared to TD participants, reported experiencing feeling closer to their partners regardless of the partner's diagnosis. The authors speculated that this might be because people with ASD tend to be excluded from social interactions in daily life. Therefore, a conversational encounter might feel closer, whereas, for the TD group, such an interaction might be more common and thus less intimate.

1.1.4 MOVEMENT

Clumsiness, movement coordination, and general motoric impairments have long been associated with ASD (Asperger, 1944). Atypical motor production has been reported in ASD, for example, difficulties in movement control and execution (Bo et al., 2016). Moreover, repetitive movements were observed, which did not contribute to an ongoing interaction and caused misunderstandings in interactions of individuals with ASD (Bo et al., 2016). Crippa et al. (2015) distinguished children with and without ASD by analyzing their upper-limb movement in a motor task, indicating substantial differences in this domain. Another study found several motor impairments in children with ASD, such as

[3] More specifically, TD participants experienced physiological calming when the partner provided high levels of social affiliation; however, providing affiliation led to increased arousal of the nervous system, indicating bodily distress. In contrast, ASD participants reacted with heightened arousal levels to affiliation shown by their partners, suggesting increased stress.

lower motor scores and higher movement variability than the control group (Kaur et al., 2018). In adult participants with ASD, atypical movement kinematics were recorded, such as moving with higher velocity (Cook et al., 2013), and essential motor coordination differences were detected across various behavioral contexts (Fournier et al., 2010). In infants with ASD, Colgan et al. (2006) found reduced variability in the type of gestures, while the total number of gestures did not significantly differ between infants with and without ASD. These findings are in line with de Marchena & Eigsti (2010), who found that adolescents with ASD spoke and gestured with a similar frequency in a narrative task to the control group but with quality aberrations in these domains. Another study observed that movement from individuals with ASD during dyadic interactions did not demonstrate a lack of quantity but rather quality (Georgescu et al., 2020).

1.2 INTERPERSONAL SYNCHRONY

1.2.1 THE CONCEPT

Synchrony, a phenomenon underlying social interaction, can be defined as temporal coordination and simultaneous or shortly delayed alignment of various behaviors, such as body movement (Georgescu et al., 2020). People can act synchronously, for example, by producing body movements during a similar time as their interaction partner[4]. Consequently, Cacioppo et al. (2014, p. 842) described synchrony between persons as the "temporary alignment of periodic behaviors with another person". Aside from establishing a successful interaction, synchronous body movement, for example, improves subsequent problem-solving in dyads leading to more effective collaboration (Miles et al., 2017).

[4] It is essential to mention that synchrony should not be confused with mimicry, which can also increase social affiliation but is exact copying of behavior (Lakin & Chartrand, 2003).

Synchrony is a broad term used to describe various phenomena (see also Schoenherr et al., 2019). Synchronous movement is one facet of synchrony; however, synchrony is a far broader term that can also describe, for example, the alignment of heartbeat, blood pressure, brain activity, and walking rhythm between two or more individuals (e.g., Wiltermuth & Heath, 2009). Different expressions, for example, the terms nonverbal synchrony (e.g., LaFrance, 1979; Ramseyer & Tschacher, 2011), interactional synchrony (e.g., Bernieri et al., 1994), and interpersonal synchrony (IPS; e.g., Hove & Risen, 2009; Miles et al., 2009; Georgescu et al., 2020) are used to describe this phenomenon[5]. IPS facilitates social interactions and is a crucial component of successful encounters between human beings. Further research addressing IPS in different contexts and gaining a more enhanced comprehension of this vital concept and its perception is necessary to understand underlying mechanisms of regular and impaired social interactions e.g., within the scope of psychiatric or developmental disorders.

1.2.2 SYNCHRONY IN TD INDIVIDUALS

In TD individuals, movement synchrony impacts various matters, such as interpersonal brain-coupling and is associated with better psychotherapy outcomes (Koole & Tschacher, 2016; Ramseyer & Tschacher, 2011). A meta-analysis investigated the influence of synchrony on several domains, showing a positive effect on prosocial behavior, perceived social bonding, and positive affect (Mogan et al., 2017). Various researchers have long discussed nonverbal behavior and acting in a coordinated manner as a crucial element of feelings of rapport between interactants (LaFrance, 1979; Tickle-Degnen & Rosenthal, 1990). This emphasizes the importance of synchrony regarding social connection and affiliation. Synchrony was shown to be associated with dissolving

[5] Additionally, the concept of *intra*personal synchrony (Bloch et al., 2019) refers to the coordination of different processes within one person, such as coordination and integration of thoughts, behavior, and somatic procedures.

self-other boundaries (Paladino et al., 2010) and increasing compassion (Valdesolo & Desteno, 2011), as well as rapport (Miles, Nind, et al., 2009).

Additionally, synchrony generally promotes and fosters cooperation modulated by social attachment (Szolnoki et al., 2013; Valdesolo et al., 2010; Wiltermuth & Heath, 2009). In the presence of highly synchronous stimuli, it was shown that social affiliation and emotional connection notably increased (Cacioppo et al., 2014; Hove & Risen, 2009; Lumsden et al., 2014; Tarr et al., 2016; Wiltermuth, 2012). Moreover, interpersonal liking predicted increased IPS in a naturalistic conversation task (Paxton & Dale, 2013). Alternatively, research suggests that social resentment, such as interacting with a partner who showed up late for a mutual task, can lead to reduced synchronous behavior (Miles, Griffiths, et al., 2009).

Besides the previously described high impact of synchrony on social affiliation, research on TD participants demonstrated the positive relationship between synchrony and affect (Mogan et al., 2017). In a dyadic interaction study, IPS increased positive affect, an effect that was more substantial in female dyads (Tschacher et al., 2014). Moreover, synchrony boosts self-esteem when synchronous movement occurs with a partner (Lumsden et al., 2014).

Whereas it was broadly investigated how synchrony influences affect and social affiliation, the participants' perception of synchrony remained a lack in the literature. In one study, the reported synchrony perception after engaging in virtual interactions suggested an accurate relative perception of synchronous versus asynchronous nonverbal behavior in TD participants (Cacioppo et al., 2014). Besides the study mentioned above, the reported perceived synchrony from participants who engage in a naturalistic interaction themselves and are not solely observers has not been widely investigated, even though it would likely provide comprehensive insight into how these interactions are processed and how this might differ between participants from different diagnostic groups. Enhanced insight about perception in individuals with ASD compared to TD individuals would likely contribute to an advanced understanding of the causes of observed IPS variations in ASD.

1.2.3 SYNCHRONY IN INDIVIDUALS WITH ASD

Rhythmic motor coordination during social interactions was observed to be impaired in psychiatric disorders, such as social anxiety disorder (Varlet et al., 2014), depression (Paulick et al., 2018), and was indicative of symptom severity in patients with schizophrenia (Kupper et al., 2015). Likewise, in ASD, alterations in nonverbal behavior can be observed. Individuals with ASD often struggle to achieve smooth social interactions, leading to difficulties in the social domain (AWMF, 2016). Nonverbal communication deviations in ASD have been suggested, but these observations' mechanisms remain unclear. One mechanism might be that they do not produce similar levels of synchrony during social interactions compared to TD individuals, as recent findings indicate (Georgescu et al., 2020; Koehler et al., 2021; McNaughton & Redcay, 2020), even though body movement coordination above chance is present in individuals with ASD (Romero et al., 2018). Across several domains (motor, conversational, physiological, and neural), IPS can be considered attenuated or atypical in dyads in which individuals with ASD interact with TD individuals (McNaughton & Redcay, 2020). Bloch et al. (2019) conceptualize that *intra*personal synchronization is one important factor contributing to *inter*personal synchrony. *Intra*personal synchronization refers to, for example, the coordination of communicative signals, such as temporal processing (Bloch et al., 2019). Indeed, temporal processing is a relevant contributor to communication and is altered in individuals with ASD compared to TD individuals (Falter et al., 2013; Falter et al., 2012 (a); Falter et al., 2012 (b); Isaksson et al., 2018; Lambrechts et al., 2018; Menassa et al., 2018). These aberrations most likely relate to communicative impairment in individuals with ASD (Noel et al., 2018), presumably affecting IPS. In addition to atypical temporal processing, Vogel et al. (2018) indicated altered inner time experience in individuals with ASD (*interrupted experience of time* in ASD), which might contribute to the characteristic tendency in ASD to implement rigid routines and could also influence IPS.

As mentioned before, IPS is reduced in mixed dyad types (TD-ASD) and ASD dyads (Georgescu et al., 2020)[6]. Given that synchrony mediates smooth social interactions, reduced IPS in mixed dyad types might contribute to the TD individuals' perception of socially awkward interactions with individuals with ASD. Thus, it is substantial to investigate further the mechanisms leading to attenuated interaction quality. The cooperative nature of communication and the interest in engaging and sustaining social interactions appears to be diminished in ASD (Hobson & Lee, 1998; Zapata-Fonseca et al., 2018). In another study investigating IPS, participants with ASD demonstrated less IPS in a natural conversation with an experimenter for the head and hand but not for the trunk region of the body (Noel et al., 2018). In the referred study, the authors showed less movement complexity in individuals with ASD compared to TD participants. However, movement complexity did not correlate with synchrony, which implies that alterations in movement complexity do not sufficiently explain alterations in IPS observed in ASD. Brezis et al. (2017) demonstrated that participants with ASD showed lower rates of synchronized motion in a mirror game than TD participants, partially explained by participants' motor skills. In a narrative task, speech and gestures were less synchronized in adolescents with ASD compared to the control group, suggesting a disintegration of verbal and nonverbal communication (de Marchena & Eigsti, 2010).

[6] These findings of reduced IPS in ASD independent of partner diagnosis contradict the *Interactional Heterogeneity Hypotheses*, which suggests that individuals with a somewhat different background exhibit more problematic social interactions due to their heterogeneity (see Georgescu et al., 2020; Bolis et al., 2017).

A vast body of literature shows the presence of atypical or reduced IPS in children with ASD (e.g., Fitzpatrick et al., 2017), associated with a more neutral affect (Yirmiya et al., 2006). For example, children with ASD produced less IPS while performing upper and lower limb movements with a partner (Kaur et al., 2018). Additionally, IPS has been broadly investigated using rhythmic paradigms. Using a rocking chair paradigm, children with ASD did not show a tendency to synchronize their rocking rhythm with their caregivers, in contrast to TD children, who exhibited stronger in-phase coordination (Marsh et al., 2013). Using a pendulum coordination paradigm, adolescents with ASD showed reduced interpersonal coordination (Fitzpatrick et al., 2016).

Synchrony is also known for affecting empathy. It is essential to differentiate between cognitive and affective empathy (Thaler et al., 2021). For instance, individuals with ASD tend to show typical affective responses when presented stimuli about victims of aggression but showed reduced performance in a ToM task; a pattern found to be opposite to that of participants with psychopathic tendencies (Jones et al., 2010). Coordinated movements are considered to foster the quality of empathy and prosocial behavior. Therefore, a dance and movement intervention might be helpful for people with difficulties in the domain of empathy (Behrends et al., 2012). IPS can be seen as a mediator in cognitive empathy and is present but attenuated in ASD (Koehne et al., 2016). However, the authors indicate that this mechanism might differ in individuals with ASD. Participants with ASD perceived differences in synchrony in an interactive finger-tapping task; however, this did not lead to a similar mediation of cognitive empathy as observed in the control group (Koehne et al., 2016).

1.3 OVERVIEW OF THE OVERARCHING PROJECT

This dissertation was realized as a subproject of an overarching study (Nelson et al., in prep.) that included four different individual tasks in one long session, lasting approximately 4 hours. The study contained a computer task using a perceptual simultaneity paradigm (adapted from Falter et al., 2012 (a)) that investigated temporal perception, two fMRI tasks, and a *conversational task*, which is the focus of this dissertation. In the *conversational task*, participants talked for 20 minutes to a previously unacquainted TD confederate. The TD confederates were naïve to the participant's diagnostic group. The experimenters instructed the interaction partners to discuss specific topics (*hobbies* and *meal planning*, adapted from Tschacher et al., 2014) . The conversation was videotaped for subsequent analysis of IPS using the frame-differencing method Motion Energy Analysis (MEA; Ramseyer & Tschacher, 2011; Ramseyer, 2020). Before and after the conversation, participants answered the Positive and Negative Affect Scale (Watson et al., 1988), a questionnaire regarding affect. They additionally filled out a questionnaire measuring social affiliation and reported perceived synchrony[7] after the task (adapted from Cacioppo et al., 2014; for more details, see Appendix C).

In the task using a perceptual simultaneity paradigm, participants had to judge whether the onset of bars on a computer screen was simultaneous, aiming to detect visual temporal perception thresholds in each group. The two fMRI tasks focused on the neural correlates of synchrony perception. One task was adapted from a previous study (Cacioppo et al., 2014). In this experiment, participants communicated with alleged partners using back-and-forth keyboard tapping while lying in the scanner. The interaction was virtually represented on a screen within the participant's sight. The experimenters told the participants that their partners communicated with them from another room, but responses were computer-generated. Responses varied in latency and latency variance, simulating communication conditions with higher synchrony (short interval between tapping and response) or lower synchrony (long interval between

[7] The term perceived synchrony in this project merely refers to self-reported perception of synchrony and should not be confused with other aspects of perception, such as neural perception, which is not assessed in this thesis.

tapping and response). In the second fMRI task, participants observed short, silent video clips of a dyadic interaction. In each video clip, either an individual with ASD interacted with a TD individual or two TD individuals interacted with each other[8]. Consequently, the videos contained relatively low or relatively high synchronous behavior. The activation of different brain regions will be analyzed as part of the more extensive study. The in-scanner tasks aimed to explore perception patterns of synchronous and asynchronous conditions within participants with ASD compared to TD participants. In summary, this dissertation is based on one of the four tasks of the overarching project: the *conversational task*.

1.4 AIMS OF THE PRESENT STUDY

Considering the severity of communication and interaction difficulties often present in individuals with ASD and their impact on quality of life, it is highly relevant to provide a fundamental understanding of the underlying mechanisms of the most prevalent symptoms of ASD. Given that individuals with ASD often struggle to manage social interactions fluently, interventions have been created for this target group to, for example, establish turn-taking behaviors and develop social communication skills, leading to smoother social interactions (Bambara et al., 2018; Rieth et al., 2013). To further develop specific and beneficial support for individuals with ASD, it is crucial to precisely understand the mechanisms leading to different interactive behavior in ASD. Therefore, this study investigated differences in social interaction patterns and perception between participants with and without ASD, aiming to provide an enhanced fundamental and contextual understanding of interaction and communication difficulties observed in ASD.

[8] Adapted from Georgescu et al., 2013

It has been shown that IPS influences social interactions and differs between homogeneous TD dyads and dyads consisting of at least one individual with ASD (e.g., Georgescu et al., 2020). These findings raise the research question about the relationship between synchrony perception and synchrony production and how the two influence each other. Given that perceptual processes play a fundamental role in social interactions and highly influence behavior, it is important to assess how perception possibly varies between ASD and TD individuals. The perspective from TD participants on individuals with ASD has been broadly investigated; however, the reported perception of social interactions from individuals with ASD remains a relatively under-investigated domain. Perception is a starting point for numerous downstream processes and can crucially influence behavior. Hence, it is fundamental to investigate perceptual patterns to better understand observed variations in the behavior of individuals with ASD compared to TD individuals.

It has been hypothesized that reduced synchrony in production might be due to difficulties in correctly perceiving timing of behaviors in interactions. Investigating how or whether at all individuals with ASD perceive synchrony variations in a conversation could provide relevant insights on this matter. Many studies have extensively investigated the influence of synchronous stimuli or conditions on various domains (for example, dancing in synchrony leading to enhanced social bonding; Tarr et al., 2016). However, only a few studies have examined IPS between people interacting in a naturalistic conversation, yet the underlying perception remained widely unknown. Given that evidence suggests that synchrony interventions can lead to enhanced prosocial behavior in individuals with ASD and might improve the outcomes of their interactions (McNaughton & Redcay, 2020), it is pertinent to investigate the perceptual processes that underlie atypical synchrony production in ASD. Beyond that, multiple studies suggested the potential of IPS for aiding in diagnostic procedures regarding ASD (Georgescu et al., 2019; Koehler et al., 2021; McNaughton & Redcay, 2020). A more fundamental knowledge of IPS, as it is behaviorally perceived, may contribute to diagnostic and therapeutic progression. Thus, this study investigates explicitly differences in perceived synchrony as reported by TD and ASD participants after a dyadic conversation with the aim to provide a more holistic understanding of the relations and mechanisms of social interaction difficulties in ASD.

Social bonding behavior and emotions have been shown to be influenced by IPS in TD individuals (e.g., Morgan et al., 2017). Considering reduced IPS has been observed in interactions with individuals with ASD, this leads to the question whether IPS has different effects on emotional aspects in ASD. Despite documented deviations in IPS in ASD, little research has investigated how social affiliation and affect are linked with IPS in individuals with ASD. One can question whether, in individuals with ASD, bonding behavior and emotions are substantially influenced by IPS or whether it is somewhat dissociated and other mechanisms leading to social affiliation and affect are present. Such findings of dissociation might point towards a substantial disparity between TD and ASD individuals regarding unintentional processes during social interactions with possibly varying effects on bonding behavior and affect. Hence, another aim of this study is to explore the modulatory effect of IPS on social affiliation and positive affect and possible differences between the diagnostic groups.

Besides investigating the effects of IPS, it is a central aim of this study to explore social affiliation and affect in general in individuals with ASD during social interactions. Despite the effort to improve interaction skills in individuals with ASD, little is known about how social interactions influence affect and social affiliation in adults with ASD. A coherent understanding of these relations is essential, given that social interactions and conversations influence most domains of daily life and, therefore, may tremendously impact the quality of life. Observing affect and social affiliation after a conversation might help explain differences in interactional behaviors and inform whether individuals with ASD experience the aforementioned qualities of human interactions similar or different to TD individuals. It is essential to gain insight into the experienced emotions in individuals with ASD during naturalistic interactions to assess impacts on resulting behavior appropriately[9]. Over time, advancement in understanding the causes of behavioral differences (such as emotional processes) might lead to more specific offers of support for individuals with ASD regarding social interactions, presumably reducing the risk of frequent comorbidities such as depression.

Social bonding behavior such as social affiliation might differ in individuals with ASD compared to TD individuals due to reported interaction difficulties. With possibly less social affiliation present, interaction difficulties might increase in a self-intensifying manner. Given that social affiliation is a central aspect of well-functioning cohabitation in societies and is present in most domains of daily life, precise insight into this aspect is of great importance. Potential variations in social bonding behavior between the majority of the society (TD individuals) and ASD individuals might lead to challenges in daily life. On the other hand, if social affiliation does not profoundly differ after a naturalistic conversation, this knowledge might contribute to a more accurate perspective of TD individuals on ASD, who beforehand might have experienced ASD individuals as challenging to understand or emotionally distanced due to communicative impairment[10].

Based on this reasoning, this study aimed to provide insight into the emotional state and social bonding behavior of individuals with ASD in an interactional context by

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[9] Because of present interaction difficulties, one may assume that individuals with ASD experience fewer positive feelings during these interactions. This preconception might contribute to an avoidance behavior followed by increased social interaction difficulties. If primarily negative emotions appeared during interactions, this recognition might serve as a starting point for further investigations addressing concrete reasons for these negative emotions.

[10] The same reasoning applies to understanding affect in individuals with ASD. Due to widely observed communication impairments, individuals with ASD might not be able to communicate their feelings to their counterparts adequately. However, if TD individuals could better understand the internal emotional processes of individuals with ASD, this comprehension beyond nonverbal communication could diminish negative prejudices and lead to more favorable connotations regarding interactions with ASD individuals.

scrutinizing participants' subjective experiences. Specifically, the study addressed how IPS influences social affiliation, positive affect, and synchrony perception during dyadic interactions of individuals with and without ASD. Enhanced knowledge about perception and behavior during social interactions will inform fundamental differences related to ASD and may lead to improved interventions and support for individuals with ASD. This study strives to provide further groundwork for societal understanding, including enhanced awareness and acceptance on a societal level, which may lead to increasingly sympathetic interactions and improved quality of life for individuals with ASD.

1.5 HYPOTHESES

This chapter presents three research questions (Q) regarding the variables of interest, followed by considerations regarding these questions, and finally, the corresponding hypotheses (H). All research questions and hypotheses refer exclusively to the *conversational task.*

Prior to addressing the hypotheses, IPS will first be analyzed for each of the two subtasks, *hobbies* and *meal planning.* This aims to replicate previous research, which found reduced IPS for mixed dyadic interactions (comprised of one participant with ASD and a TD confederate) than homogeneous (TD-TD) dyads in the *meal planning* subtask (Georgescu et al., 2020). The *hobbies* subtask is a relatively new task utilized to engage participants in topics that are personally interesting to them. This might be a more naturalistic conversation in daily scenarios when meeting someone than a conversation about meal planning. Given that it has been shown that IPS differs between dyad types in the *meal planning* task, it may also be the case in this more naturalistic context.

PERCEIVED SYNCHRONY

Q1: How does the *conversational task* and IPS influence the perceived synchrony when comparing the ASD and the TD group?

Rationale: There is a lack of literature regarding the perception of synchrony in dyadic conversations in ASD. It is postulated that the perception of synchrony, as reported by the participants, correlates with the actual IPS between the dyads, assuming a relationship between production and perception of synchrony. Hence, a positive relationship between IPS and perceived synchrony may be expected. However, participants with ASD have shown atypical temporal processing (e.g., Falter et al., 2013) and might therefore perceive synchrony differently than TD participants.

H1.1: Synchrony perception differs between the ASD and the TD group.

H1.2: Perceived synchrony is modulated by IPS.

SOCIAL AFFILIATION

Q2: How does the *conversational task* and IPS influence social affiliation when comparing the ASD and the TD group?

Rationale: The naturalistic face-to-face interaction likely influences social affiliation between the conversation partners. Evidence shows that participants with ASD report feeling close to their partner after a naturalistic interaction (Morrison et al., 2019). However, it might be that participants with ASD are less influenced by a short conversation on an emotional connective level (Chevallier et al., 2012). Moreover, dyads, including a person with ASD, likely produce less IPS, possibly resulting in lower social affiliation levels than in dyads exclusively consisting of TD participants.

H2.1: Social affiliation is more prominent in the TD group than in the ASD group.

H2.2: Social affiliation is modulated by IPS.

AFFECT

Q3: How does the *conversational task* and IPS influence affect when comparing the ASD and the TD group?

Rationale: Participants' positive affect might increase based on the assumingly engaging tasks that have been selected (*hobbies* and *meal planning*). This effect may be less profound in participants with ASD, given that individuals with ASD demonstrate social interaction difficulties (AWMF, 2016). Moreover, individuals with ASD struggle with emotion regulation and expression of their own emotion (Cai et al., 2018; Reyes et al., 2020). Such difficulties in affective processing may diminish the social interaction experience in ASD. Taken together, individuals with ASD might enjoy the conversation less, possibly resulting in a less profound positive affect change.

H3.1: Positive affect change is more prominent in the TD group than in the ASD group.

H3.2: Positive affect change is modulated by IPS.

2. MATERIAL AND METHODS

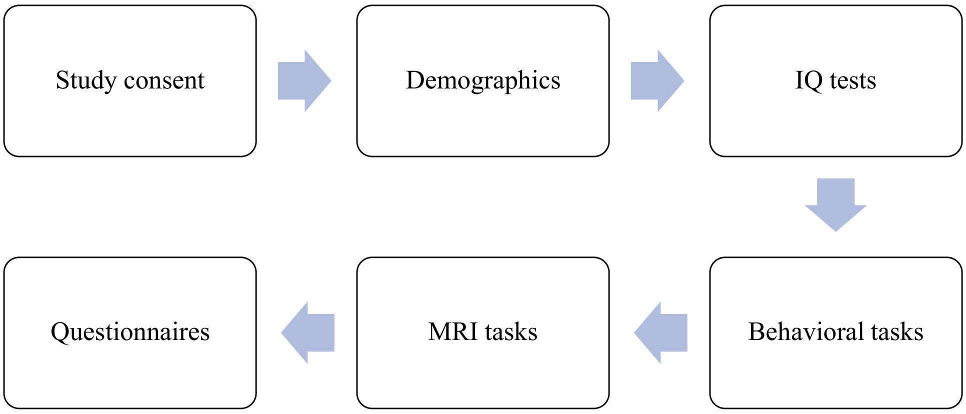
The following chapter outlines the project's methods and procedures. This study was subject to the declaration of Helsinki (World Medical Association, 2013), which outlines the ethical principles for medical research. The ethics committee of the medical faculty, Ludwig-Maximilians-Universität (LMU), has considered and approved this study (file number: 20-1050).

2.1 PARTICIPANTS

Participants were recruited from the database of the outpatient unit for ASD, medical faculty, LMU Munich. Further recruitment occurred through local and regional channels (e.g., flyers, network partners, listservs, and disclosure on several websites, including autism-specific websites). Participants were assigned to either the ASD or the TD group based on whether they had an ASD diagnosis according to the International Classification of Diseases (ICD-10; World Health Organization [WHO], 1993) . It was aimed for an equal gender, age, and intelligence quotient (IQ) distribution between the diagnostic groups. Psychiatric comorbidities and medication were recorded. One participant with ASD had to be excluded from the sample used in this study due to not fitting the inclusion criteria (IQ < 70). Thus, 23 participants with ASD remained (6 female, age M = 35.82, SD = 11.23). The total number of TD participants for the control group was 28 (10 female, age M = 34.53, SD = 11.83).

2.2 STUDY PROTOCOL

Figure 1. Study Workflow



Note. The study workflow on the testing day. Behavioral tasks included the *conversational task* (focus of this project) and the perceptual simultaneity task. For a more detailed flowchart, see Appendix B.

After arrival, participants' written consent was obtained. It was clarified to the participants that the study participation was entirely voluntary, and the consent could be revoked at any time without justification or repercussion. After the written study consent, a questionnaire about demographics and afterward IQ tests were conducted[11]. Then, either the *conversational task* or the perceptual simultaneity task followed, whereby the order was counterbalanced. The order of the two topics of conversation, *hobbies,* and *meal planning,* was also counterbalanced. The questionnaire assessing affect was filled out twice, directly before and after the *conversational task*. After the task, participants answered a questionnaire about social affiliation towards their partner and perceived synchrony. Afterward, the written MRI consent was obtained, followed by the MRI training block. Then, the two fMRI tasks took place, which were counterbalanced. The

11 In some rare cases, this order could not be kept for organizational reasons.

remaining questionnaires (see chapter Questionnaires) were either filled out between the tasks when a timeframe was available or after the MRI tasks. Participants were debriefed after completing the study. Furthermore, they received copies of their written consent and were asked to fill out the form for study reimbursement and, if applicable, reimbursement for travel costs. Additionally, participants received a copy of their brain images upon request. The chronological order was conducted with the help of an experimental workflow to ensure adherence. The fMRI tasks plus training took approximately 1 hour, the perceptual simultaneity task 10 minutes, and the *conversational task* around 20 minutes in total (maximum 4 hours overall).

2.3 CONVERSATIONAL TASK

Participants engaged in a *conversational task* with a TD confederate serving as the conversational partner. The task consisted of two topics: (1) freely talking about their *hobbies* and interests and (2) designing a menu with food and drinks they both dislike (*meal planning).* Both tasks offered an open structure, allowing participants and confederates to engage in the conversation freely. The specific subtask *hobbies* has been selected, given that special interests are a diagnostic criterion for ASD (AWMF, 2016). This topic might lead individuals with ASD to engage in a more one-sided verbal exchange by discussing their hobbies in detail. In the subtask, *meal planning*, the participant's conversational topic was to design a five-course meal with foods and drinks that both conversational partners disliked. Furthermore, they were instructed to design further courses if the time should allow before the experimenters re-entered the room when the time was up. This task was chosen for its turn-taking and cooperative manner and has been used in studies before (Georgescu et al., 2019; Georgescu et al., 2020; Tschacher et al., 2014). The topic of each conversation was predetermined and instructed by the experimenter directly before the conversation.

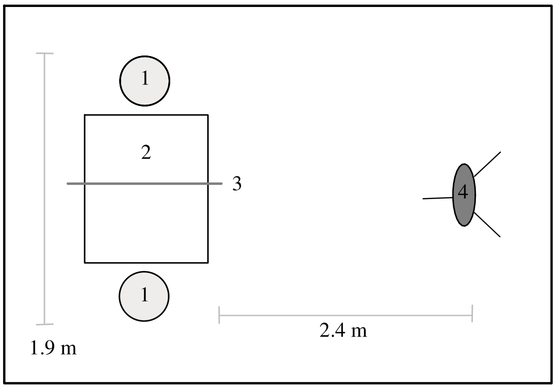
The interactions were recorded with a camera and later analyzed with MEA (Ramseyer & Tschacher, 2011) to evaluate head and body movements and interactional synchrony. The audio was recorded with two headset microphones attached to the participant and confederate. Each conversation lasted 11 minutes, from which approximately 10 minutes were later used for video analysis. Once the script started, a movie clapboard signaled the participants to commence the first conversation and later audio synchronization. Simultaneously, the experimenters left the room. After 11 minutes, the experimenters re-entered the room, explained the second conversation's topic, and repeated the procedure.

Confederates were people from the research group or recruited from outside the clinic. They were naïve to the participant’s diagnoses. Confederate and participant were unacquainted before the testing. Confederates had to speak German fluently (C2 level). They received instructions for the *conversational task* with the participant but no additional information to facilitate a naturalistic social interaction. In total, for this sample, ten confederates (seven female, three male) were recruited. It was conceptualized that each confederate had to engage in six conversations and interact with the same number of ASD and TD participants. This approach should control for synchrony imbalances from the confederates[12].

[12] For this preliminary sample, a perfect counterbalance was not achieved. As a result, the confederates underwent between four and six conversations. Five confederates engaged equally with TD and ASD participants; the other five confederates engaged with more TD than ASD participants.

2.4 EXPERIMENTAL SETUP

Figure 2. Testing Room



Note. The layout of the testing room (perspective from above). The room included (1) two chairs, (2) a table, (3) plexiglass due to COVID-19 hygienic requirement, and (4) a tripod camera for movie recordings (C922 Pro HD Stream Webcam, Logitech). Markings on the floor ensured the same position of the devices through all testings.

All experiments were performed in the Clinic of Psychiatry and Psychotherapy at the LMU Hospital Munich in Germany. All testing for this project took place in the same room designated specifically to study experiments (see Figure 2). For the *conversational task*, the participant and confederate sat opposite each other in a stable seating arrangement. Headset microphones (t.bone earmic 500, Thomann GmbH) were attached to the confederate and participant. The audio recorder (Zoom H4n, Zoom Sound Service GmbH) lay between the participants on the table's edge. The device was connected to a laptop and transmitted the audio recordings from the microphones. Audio settings were individually adjusted. The task was conducted in the study room, where stable background and light conditions were established with two blinds and bright artificial lighting. This homogeneity was crucial for later video analysis with MEA.

2.5 QUESTIONNAIRES

At the beginning of the study, participants answered the questionnaire Demographics with disclosure about their age, medical history, alcohol consumption, handedness, and vision, among other things. The nonverbal IQ was measured by conducting the Cultural Fair Intelligence Test-20-revised (CFT-20-R; Weiß, 2006), which is an assessment of formal-logical thinking to ensure the compliance of the inclusion criteria (IQ >70) and look out for IQ group differences, which may affect the task results[13]. The nonverbal IQ was assessed through the Mehrfachwahl-Wortschatz-Intelligenztest (MWT-B; Lehrl et al., 1999). Participants had to correctly recognize existing German words in a series of otherwise nonsense words. The participants did both tests on paper, and the ticked solutions were later added to Centraxx[14] by the experimenters for digital storage. Affect was evaluated before and after the conversational task with the German version of the Positive and Negative Affect Scale (PANAS; Krohne et al., 1996; Watson et al., 1988). The PANAS consists of 20 words describing different emotions, ten assessing positive and ten negative affect using a 5-point Likert scale (1 = "not at all", 5 = "very much"). Social affiliation and perceived synchrony were assessed with a questionnaire containing seven items (see Appendix C) after the *conversational task* as previously established (Cacioppo et al., 2014). The questionnaire score means were computed for each participant to get the final values for social affiliation, perceived synchrony, and positive affect before and after the *conversational task*. The positive affect change was computed to correct baseline differences in affect by subtracting the positive affect mean after the *conversational task* from the positive affect mean before the *conversational task*. Autistic traits were assessed through the Autism Quotient (AQ;

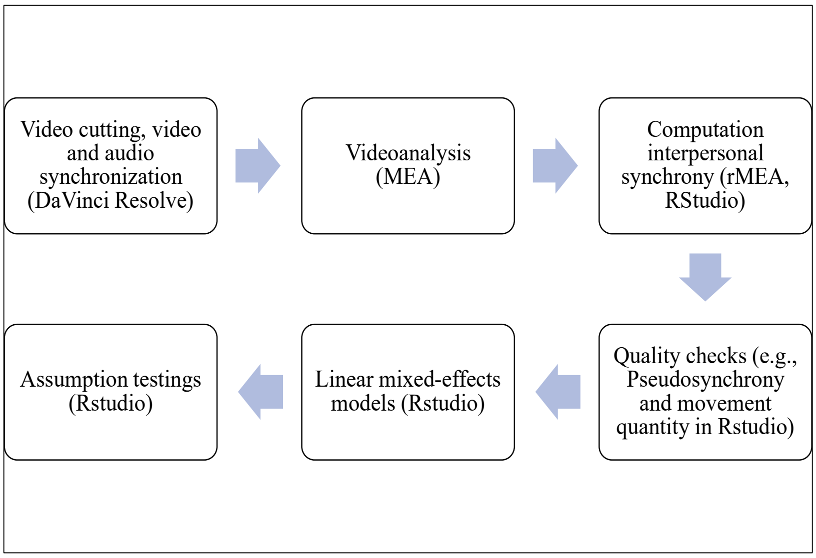
[13] 25 participants (13 TD, 12 ASD) underwent the IQ test in another study before. To prevent distorted test results due to a possible training effect in repeated testing, the IQ scores from these participants were extracted from the study before after receiving the participants consents.

[14] Centraxx is a digital platform used in clinical settings for research purposes (version 3.18.1.22).

Baron-Cohen et al., 2001). Additionally, empathy and dyspraxia were evaluated through the Saarbrücker Persönlichkeitsfragebogen (SPF; Paulus, 2009) and the Adult Dyspraxia Checklist (ADC; Kirby et al., 2010), respectively. All questionnaires were answered on an iPad (8th generation) and digitally stored in the secure system Centraxx to ensure safe and functional data storage.

2.6 PREPROCESSING

Figure 3. Preprocessing and Analysis Workflow



Note. This figure shows an overview of the individual preprocessing and analysis steps conducted in this study.

All videos were individually examined for stable light condition, correct chair positioning, and framerate (30 frames per second). Audio and video data were manually checked for recording quality and proper length. Audio data underwent further inspection and quality check using Praat 6.1.04 (Boersma & Weenink, 2011). However, only video recordings were relevant for data analysis for this project. Participants with missing data throughout both topics from the *conversational task* would be excluded from further analysis. Missing data because of videos with frame drops greater than 10% of the whole video, dyads not finishing the task, interrupted video recording, or because videos did not fulfill the requirements for MEA (e.g., lightning instability) were imputed with the appropriate diagnostic group mean. One video in the subtask *hobbies* from a TD participant from this preliminary sample was invalid because of unstable lightning. Thus, the missing value was replaced as described above. The same procedure applied for three missing SPF scores, one missing ADC score from the TD group, and one missing IQ CFT score from the ASD group. Video and audio were synchronized and cut with DaVinci Resolve 17 (Black Magic Design, 2019). The first 54 seconds (1620 frames) were trimmed because scenes unrelated to the task were recorded (e.g., the experimenters giving the signal to start the task), which left 10:06 minutes of video length for each conversation. The subsequent analysis excluded the first second when loading the data set into rMEA because the first second mainly transports noise. Additional five seconds were recorded to avoid data loss due to window cross-correlation in rMEA. This process left precisely 10:05 minutes of video material for IPS analysis.

2.6.1 MOTION ENERGY ANALYSIS

In line with recent studies, the video analysis in this study was accomplished using MEA (Ramseyer & Tschacher, 2011). MEA is a specifically developed software program to objectively detect non-verbal communication and automatically quantify the amount of head and body movements through frame-differencing algorithms (Ramseyer, 2020). This method relies on extracting differences between video frames by detecting grayscale pixel changes. Movements are quantified, whereas the movement direction is not detected. The MEA version 11.b was used for all video analysis. The MEA procedure was followed as described in Tschacher et al. (2014). After reading the video, the predefined regions of interest (ROI) for later interpersonal synchrony analysis had to be manually defined using a color marker. A fixed coloring procedure was conducted: first, the participant's head was highlighted in color randomly assigned by MEA (ROI I), then the participant's upper body, including arms and thighs (ROI II). Next, the confederate's head (ROI III) and body (ROI IV) were marked, resulting in four differently colored areas for the four regions of interest[15]. The region below the knee was not highlighted, as the conversation partner could not see this body part. Movements from that body region were considered irrelevant, as they could not be interpreted as IPS in this study but only occasional movement and, hence, noise. These specific regions of interest were chosen to distinguish between head and body synchrony. However, this study focuses on IPS of the head region. This region is the most plausible to be looked at by the conversational partners in this specific experimental setting, given that the lower body could not be seen because of the table between the participants. The detection threshold for grayscale pixel changes frame by frame for each ROI was adjusted to 8 (default threshold = 20). If the threshold were too low, too much noise would be detected. Alternatively, some movements would not be registered if the threshold was too high. The specific threshold of 8 for this study was carefully chosen because it was a good balance in detecting most movements from the dyads without causing too many artifacts within these specific video recordings. This estimate was ascertained through visual inspection and plotting using multiple thresholds from 5 to 25 to find an applicable threshold (see also instructions and recommendations using MEA in Ramseyer, 2020) . After these steps, previous data had to be cleared, and MEA could be started. After running MEA, a .txt file was saved containing the raw data generated in MEA, representing the time-series of motion energy data of the assessed dyad (Ramseyer, 2020)[16]. After successfully running MEA, a

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[15] Highlighting was done starting from the beginning of the video and going through the sequence with a slider, adjusting the ROIs when head or body movement from one of the conversation partners occurred to achieve high accuracy. The procedure of positioning the ROI was kept constant for all analyses.

[16] More detailed, each .txt file entailed 18.180 rows. Each row represented the following frame-difference from the video of the assessed dyad (10:06 minutes video material gives 606 seconds of video material with 30 frames per second, which leads to 606 x 30 = 18.180 video-frames). Each of the nine columns in the file represented a different ROI: For this study, only 4 ROI were defined; therefore, the last five columns only contained zeros and were not considered. For further information, see Kleinbub & Ramseyer, 2021.

screenshot of the program and its settings was saved for sanity checks. The output files were visually checked for data plausibility (for further information regarding MEA, see Appendix B).

2.6.2 CROSS-CORRELATION ANALYSIS

All further processing and analyses occurred in RStudio (R Core Team, 2021; RStudio Team, 2020). Further data processing was done with the open-source R package rMEA (Kleinbub & Ramseyer, 2021), developed explicitly for IPS extraction from data gained by MEA. Separate rMEA scripts were used for the subtasks, *hobbies* and *meal planning,* making the output more approachable. In rMEA, the raw MEA time series for the head ROI from each dyad were used to calculate the value of each dyad defined as IPS in this study using a lagged window cross-correlation algorithm. In more detail, the time series with motion energy patterns from participant and confederate within each dyad were cross-correlated using simple Pearson correlation. These cross-correlations from each video window were later Fisher´s Z transformed and their means computed, resulting in one IPS value for each dyad for the head ROI[17]. Cross-correlations were calculated in windows of 30 seconds because segmenting the video in smaller segments controls temporal changes during the conversation. This concept is also referred to as the non-stationarity of synchrony (Ramseyer, 2020). A window size of 30 seconds is considered a standard approach (Kleinbub & Ramseyer, 2021). The increment size was 15 seconds, shifting the window 15 seconds forward each time. Fifteen seconds increment size, exactly half of the window size, was chosen to not lose any synchrony right between sequential windows. The settings were set so that movements with a +/- 5 second lag in both directions were detected, meaning that movements at the same time (lag = 0) were

[17] Body and total ROI were not of interest for the analysis in this study, but for a visual overview see Appendix B.

considered and 5 seconds before and after the interaction partner moved. These settings have been used before and are recommended by the developers (Ramseyer, 2020). In summary, in a first step, a simple Pearson correlation was calculated between the head movements of the two interaction partners within each window. In a second step, one motion energy time series of one partner was shifted towards the motion energy time series of the other partner in one-second steps + and – 5 seconds (lag). In a third step, the analysis window was moved forward by 15 seconds (15 seconds increment size), and steps 1 to 3 were repeated. In this study, rescaling was applied to account for different sized ROI and different movement magnitudes. Smoothing was not used, as smoothing can lead to auto-cross-correlation and data loss[18]. For more details regarding the calculation process of IPS with rMEA, refer to Kleinbub & Ramseyer (2021) .

2.7 QUALITY CHECKS

2.7.1 PSEUDOSYNCHRONY

Using this approach, pseudosynchrony, or the coincidental synchronous movement between the interaction partners, had to be considered. To control for this and not distort the actual synchrony values, pseudosynchrony had to be calculated and compared with the actual IPS values. To achieve this, pseudosynchrony samples were created by shuffling the MEA time series of the participants with the MEA time series of the confederates (between-subjects shuffling; see Kleinbub & Ramseyer, 2021) . By this, 2000 (1000 for *hobbies*, 1000 for *meal planning*) pseudo-dyads were created, always consisting of one participant and one confederate. These pseudo-dyads have never interacted with each other in reality. The pseudo-dyads always consisted of one

[18] In rMEA, rescaling can be applied to the data, which refers to transforming absolute movement to relative movement. Also, smoothing is an option: it replaces the participant's actual motion energy time-series with their average movement (Kleinbub & Ramseyer, 2021).

confederate and one participant, given that each real dyad was also comprised of this composition. Then, the same cross-correlation approach earlier used for the IPS computation was used for the pseudosynchrony computation. A Mann-Whitney test was performed to assess IPS and pseudosynchrony differences as a quality check.

2.7.2 MOVEMENT QUANTITY

As movement might be a confounding factor of IPS (Koehler et al., 2021), it must be considered in the analysis if significant movement differences between groups exist. In rMEA, a movement quantity (MQ) percentage was computed for each participant and confederate from each dyad (head region). This computation happened by analyzing in how many video frames the person showed any head movement (pixel change above the threshold for the head region and therefore a value above 0 in the corresponding row in the MEA output file) out of all the possible frames. Thus, MQ does not refer to an amount or quality of movement in this context but rather how often participants moved their heads throughout the time series. The mean relative head movement was calculated for each dyad to account for possible differences in MQ between the two groups. After computing the group mean, diagnostic group differences were checked with an independent samples t-test.

2.8 STATISTICAL ANALYSIS

This chapter provides an overview of the statistical tests conducted to assess the variables of interest in this study. For the main analysis, linear mixed-effects (LME) models were applied.

A preregistration on Open Science Framework (OSF) for a prospective publication with the whole sample was done before data collection on August 13, 2021. This study considered a *p*-value of .05. Questionnaire results are presented for the IQ tests

CFT (nonverbal IQ) and MWT (verbal IQ) and several questionnaires, including the AQ (autistic traits), ADC (dyspraxia), and SPF (empathy). Data is presented by mean, standard deviation, and group comparison (*p*-value). Additionally, descriptive statistics were established for all variables of interest between groups. IPS (head ROI), affect, social affiliation, and perceived synchrony were defined as the dependent outcome variables. The analysis used the baseline-corrected affect by computing the positive affect change over time. Diagnostic group (ASD and TD), IPS (models 2 - 4), movement quantity (head ROI), and IQ served as the independent predictor variables. Relations between possible influencing factors and the four outcome variables were analyzed separately using linear mixed-effects models from the *nlme* package (Pinheiro et al., 2021) in RStudio (RStudio Team, 2020). As predictor variables, the diagnostic group was entered in the model and IPS (from the head ROI, models 2 - 4), including their interaction. Movement quantity (also from the head ROI) was added as a covariate to explicitly control this factor. Confederates were entered as random effects, accounting for variance between the confederates.

Partially replicating previous research (Georgescu et al., 2020), the influence of the diagnostic group on IPS was analyzed separately in the subtasks *meal planning* and *hobbies*. The purpose was to uncover possible differences in IPS against the background of different conversation topics. The general model syntax in RStudio for the outcome variable IPS (either in the subtask *hobbies* or *meal planning*) was as follows:

Model 1.1 and 1.2: lme(IPS_hobbies *or* IPS_mealplanning ~ diagnostic group + movement quantity + IQ, random = list(~1|Confederate), data = dataset)

The general model syntax for the outcome variables perceived synchrony, social affiliation, and positive affect change was as follows:

Model 2-4: : lme(perceived synchrony *or* social affiliation *or* affect change ~ diagnostic group * IPS + movement quantity + IQ, random = list(~1|Confederate), data = dataset)

For models 2-4, the covariate IPS consisted of the mean IPS across both tasks because the outcome variables perceived synchrony, social affiliation, and affect were measured only once after completing both conversational subtasks and not between them. It was of interest whether IPS influences the aforementioned outcome variables, but for these models, it was irrelevant whether IPS differed between the two subtasks. Entering IPS from *hobbies* and IPS from *meal planning* separately into the models would have caused an even higher number of covariates, resulting in higher uncertainty with greater confidence intervals and diminishing the models validity given the relatively small sample size.

All predictors were analyzed when the others were held constant in the first step to address the hypotheses. In a second step, the interactions between the predictors diagnostic group and IPS and their influence on the outcome variables of models 2 - 4 were analyzed. Mean-centering was applied on IPS when entered as a predictor variable into an interaction with the diagnostic group in models 2 - 4 to make the results interpretable and informative. To control for the IQ differences between the ASD and TD groups in the measured sample, IQ scores from the CFT were added to the model as a covariate. To ease interpretation, the IQ scores were shifted such that the average population IQ (100) is represented by a numerical value of 0. As a result, the intercept is estimated for a person with IQ of 100. The model fit results were reported with support from the *report* package in RStudio (Makowski et al., 2020). Plots were compounded using the package *ggplot2* (Wickham, 2016). The assumptions of each model were checked by visual inspection of the model's residuals.

3. RESULTS

This chapter presents the results and observations of the *conversational task*. The present analysis aims to identify the relationship between the theorized predictor variables (diagnostic group, interpersonal synchrony, and movement quantity) and the studied outcome variables (social affiliation, positive affect change, and perceived synchrony).

3.1 DESCRIPTIVE STATISTICS

Mean values were computed for IQ tests, age, and questionnaire scores for both diagnostic groups and are presented in Table 1. For descriptive statistics of the variables of interest, see Table 2. An exploratory correlation matrix was computed to achieve an informative overview of the relationships between the variables of interest (Figure 4).

Table 1. Group Statistics

	ASD (n=23, 6 female)	TD (n=28, 10 female)	Group comparison
	Mean (SD)	Mean (SD)	*p*-value
Age	35.82 (11.23)	34.53 (11.83)	.595
IQ CFT	111.23 (22.76)	120.79 (15.90)	.092
IQ MWT	111.70 (11.98)	117.68 (14.86)	.117
AQ	34.61 (6.83)	14.79 (5.95)	<.001
ADC	51.13 (15.19)	20.74 (9.81)	<.001
SPF	38.43 (7.00)	44.12 (6.46)	.001

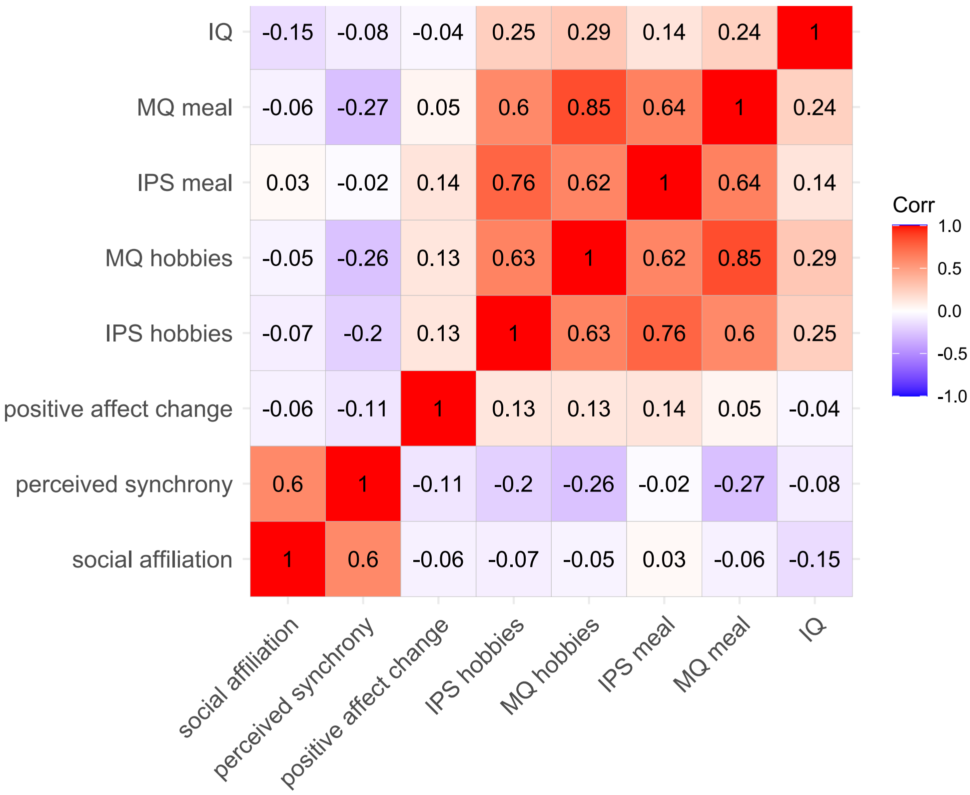
Note. Mean value, standard deviation and group comparison for age, the nonverbal IQ test Cultural Fair Intelligence Test (CFT), the verbal IQ test Mehrfachwahl-Wortschatz-Intelligenztest (MWT), the Autism Quotient (AQ), the Adult Dyspraxia Checklist (ADC) and the Saarbrücker Persönlichkeitsfragebogen (SPF) regarding empathy. For IQ group comparison, a t-test was performed. A Mann-Whitney test was performed for Age, AQ, ADC, and SPF because the data was not normally distributed.

Table 2. Descriptive Statistics Variables of Interest

	ASD (n=23, 6 female)	TD (n=28, 10 female)
	Mean (SD)	Mean (SD)
IPS *hobbies*	0.087 (0.018)	0.092 (0.013)
IPS *meal planning*	0.102 (0.026)	0.116 (0.024)
Social affiliation	5.31 (0.9)	5.55 (0.76)
Positive affect change	0.17 (0.55)	0.43 (0.36)
Perceived synchrony	4.65 (1.61)	5.64 (1.06)
Movement quantity	47.05 (11.03)	51.53 (9.91)

Note. Mean value and standard deviation for all variables of interest. Values of IPS are typically small (see Koehler et al., 2021). IPS is reported here to three decimal places for better informative value.

Figure 4. Correlation Matrix Variables of Interest



Note. This correlation matrix using Spearman correlation provides an overview of the relations between the variables of interest. The Spearman's rank correlation coefficients are reported and color-coded for visual accessibility.

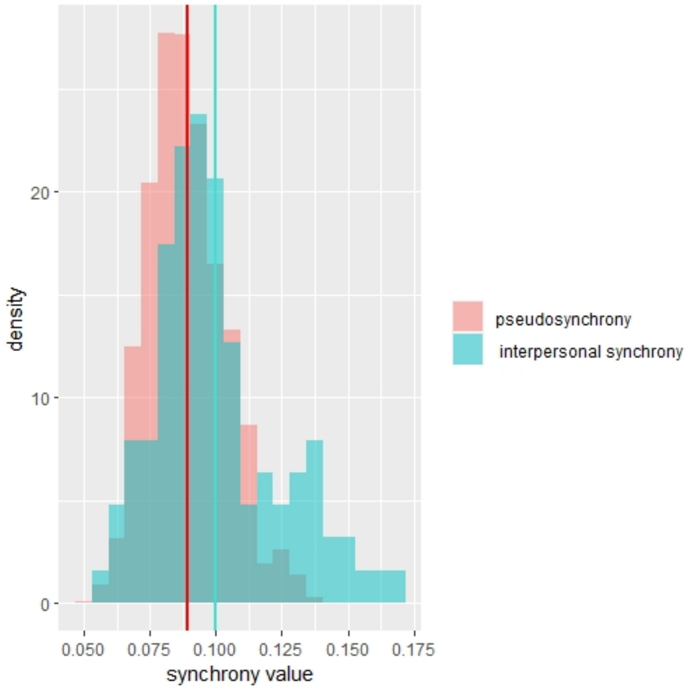
3.2 QUALITY CHECKS

3.2.1 PSEUDOSYNCHRONY

Since the head ROI IPS values will only be used in the later analysis, it was tested whether the head ROI IPS values were significantly different from the corresponding head ROI pseudosynchrony values (Figure 5). Both subtasks (*hobbies* and *meal planning*) were inspected separately for this quality check of how well IPS was computed in rMEA. Figures for visual inspection showing pseudosynchrony and IPS in both tasks separately are reported in Appendix B. Due to the between-subjects shuffling, 1000 pseudo-dyads were matched for each subtask. Their pseudosynchrony values of the head ROI for both tasks were separately computed through cross-correlation analysis. Since 51 participants engaged in both subtasks separately, 51 IPS values evolved for each subtask. As previously mentioned, one video from *hobbies* exhibited unstable lightning, leaving 50 IPS values for the *hobbies* task at this point. In both subtasks, there was a heterogeneity of variance for pseudosynchrony and IPS values, as Levene's tests indicated (p_{hobbies} = .003, p_{meal} < .001).

Hence, a Mann-Whitney test was performed for each task to compare IPS and pseudosynchrony. Given that the tests were not independent, no Bonferroni correction was done, but multiple testing should be considered. In *hobbies*, the mean IPS was 0.09 (*SD* = 0.02) and the mean pseudosynchrony 0.08 (*SD* = 0.01). The Mann-Whitney test revealed the measured IPS values from the actual dyads to be significantly higher than the pseudosynchrony values from the pseudo-dyads (*W* = 20059, *p* = .018). In *meal planning*, the mean IPS was 0.11 (*SD* = 0.03) and the mean pseudosynchrony 0.09 (*SD* = 0.01). The Mann-Whitney test revealed the measured IPS values from the actual dyads to be significantly higher than the pseudosynchrony values from the pseudo-dyads (*W* = 16512, *p* < .001).

Figure 5. Pseudosynchrony and Interpersonal Synchrony

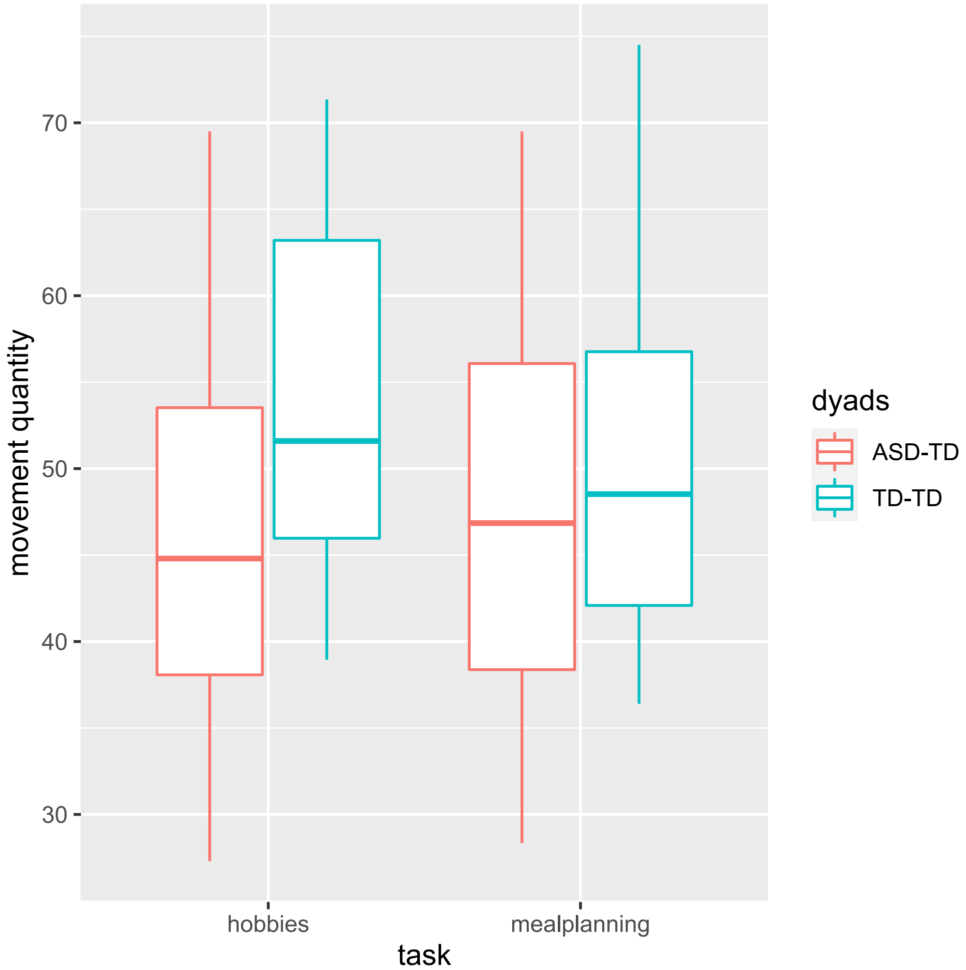


Note. Density plot for all observed synchrony values. The vertical lines represent the means for interpersonal synchrony (turquoise, n = 101) and pseudosynchrony (red, n = 2000) values. The figure demonstrates that the high synchrony values on the x-axis are exclusively interpersonal synchrony, reflecting the higher mean of interpersonal synchrony compared to the pseudosynchrony mean. This visually illustrates that IPS values assessed in this sample exceed pseudosynchrony values.

3.2.2 MOVEMENT QUANTITY

Visual exploration indicated greater MQ differences between mixed (ASD-TD) and homogeneous dyads (TD-TD) in the task *hobbies* compared *to meal planning* (Figure 6). Hence, two independent samples t-tests were performed to examine possible differences in dyadic movement quantity of the head ROI between groups for both tasks separately. Given that the tests were not independent, no Bonferroni correction was done, but multiple testing should be considered. In *hobbies*, the mean MQ was 53.44 (*SD* = 10.42) in the homogeneous dyads and 46.45 (*SD* = 10.86) in the mixed dyads. The test results revealed a significant difference between dyadic groups, with greater mean dyadic movement quantity in the homogeneous dyads, $t(46.39) = -2.29$, $p = .027$. In *meal planning*, the mean movement quantity was 50.07 (*SD* = 9.91) in the homogeneous dyads and 47.66 (*SD* = 11.92) in the mixed dyads. The test results revealed no significant difference between dyadic groups, $t(42.83) = -0.78$, $p = .442$. Even though MQ only significantly differed between dyadic groups in *hobbies*, the potentially important role of MQ became apparent. Given this result, MQ was added as a covariate into the LME models to account for this variance. This approach was decided to prevent the MQ differences from confounding the model's results.

Figure 6. Movement Quantity



Note. This box plot presents dyadic movement quantity (MQ, head ROI) separately for both tasks (*hobbies* and *meal planning*) and both dyadic compositions (either ASD-TD or TD-TD dyads, color coded). Minimum (lower end of the whisker), first quartile (lower side of the box), median (thick horizontal line), third quartile (upper side of the box), and maximum (upper end of the whisker) are shown. Higher MQ in the homogeneous than in the mixed dyads is apparent in the task *hobbies*, whereas MQ in the task *meal planning* appears more similar. For further information regarding confederates' and participants' movement quantity, see Appendix B.

3.3 ASSUMPTIONS

After fitting each linear mixed model (1-4), the model assumptions were checked by visual inspection of the residuals, including normality through Q-Q-plots and scatter plots checking homoscedasticity (see Appendix B). Checking for normality, the Q-Q-plots from each model indicated that the assumption of normality was met. The assumption of homoscedasticity was not violated, given that the model plots did not show an explicit residual structure. The variance was slightly higher with higher fitted values in the residual plot from the Model 1.2 (IPS *meal planning*). However, this was judged to be tolerable. Hence, no predictor variable was excluded, and no data transformations were performed in the models.

3.4 PRODUCED INTERPERSONAL SYNCHRONY

Two linear mixed models were fitted to predict IPS (head ROI) with the diagnostic group, movement quantity (head ROI), and IQ for each task separately. The models included the confederates as a random effect.

The Model 1.1 investigated IPS in the *hobbies* task (see Table 3 and Figure 7). Looking at random effects, the intercept standard deviation (*SD* = 8.17e-07) was smaller than the residual standard deviation (*SD* = 0.01). Consequently, the confederates did not explain much of the IPS variance. The model's total explanatory power was substantial (conditional R^2 = 0.44). IPS was marginally higher for the ASD than the TD group, while MQ and IQ were held constant; however, this effect was statistically non-significant (*b* = 2.23e-03, CI [-5.11e-03, 9.56e-03], *p* = .542). The effect of movement quantity was positive and statistically significant (*b* = 9.66e-04, CI = [6.31e-04, 1.30e-03], *p* < .001). The effect of IQ was statistically non-significant (*b* = 4.91e-05, CI = [-1.38e-04, 2.36e-04], *p* = .598).

The Model 1.2 investigated IPS in the *meal planning* task (see Table 4 and Figure 8). Looking at random effects, the intercept standard deviation (*SD* = 1.29e-02) was smaller than the residual standard deviation (*SD* = 1.52e-02). Consequently, the confederates did not explain much of the IPS variance. The model's total explanatory power was substantial (conditional R^2 = 0.67). IPS was lower for the ASD than the TD group, while MQ and IQ were held constant. This effect was statistically significant (*b* = -9.86e-03, CI [-1.89e-02, -7.81e-04], *p* = .034). The effect of movement quantity was positive and statistically significant (*b* =1.49e-03, CI = [9.66e-04, 2.02e-03], *p* < .001). The effect of IQ was statistically non-significant (*b* = -1.86e-05, CI = [-2.72e-04, 2.35e-04], *p* = .883).

Mixed dyads (ASD-TD) produced less IPS than homogeneous (TD-TD) dyads in the *meal planning* task. In contrast, the groups did not have a significant effect on IPS in the *hobbies* task. IQ did not have a significant effect in both tasks. MQ had significant positive influence on IPS in both tasks.

Table 3. Model 1.1 - Interpersonal Synchrony in Hobbies

	b	95 % CI	*t*-value	*p*-value
Intercept	3.93e-02	[2.12e-02, 5.74e-02]	4.40	<.001
Group ASD	2.23e-03	[-5.11e-03, 9.56e-03]	0.61	.542
MQ	9.66e-04	[6.31e-04, 1.30e-03]	5.85	<.001
IQ	4.91e-05	[-1.38e-04, 2.36e-04]	0.53	.598

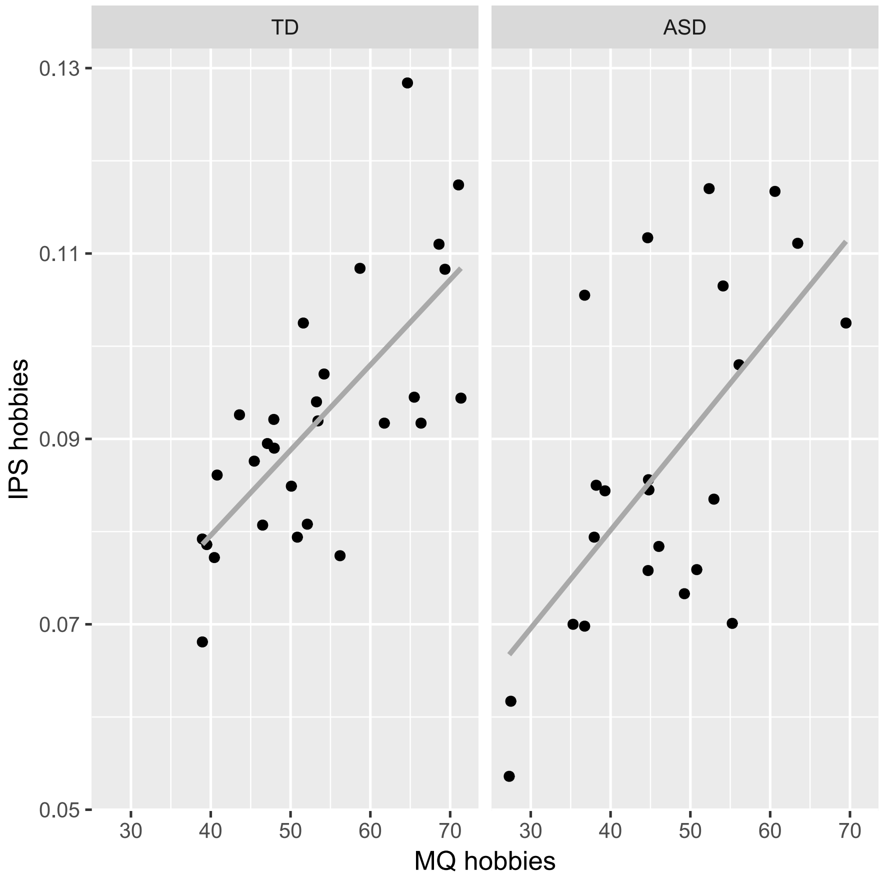
Note. *b* = beta coefficient. CI = confidence interval. Conditional R^2= 0.44.

Table 4. Model 1.2 - Interpersonal Synchrony in Meal Planning

	b	95 % CI	*t*-value	*p*-value
Intercept	4.13e-02	[1.36e-02, 6.89e-02]	3.02	.005
Group ASD	-9.86e-03	[-1.89e-02, -7.81e-04]	-2.20	.034
MQ	1.49e-03	[9.66e-04, 2.02e-03]	5.75	<.001
IQ	-1.86e-05	[-2.72e-04, 2.35e-04]	-0.15	.883

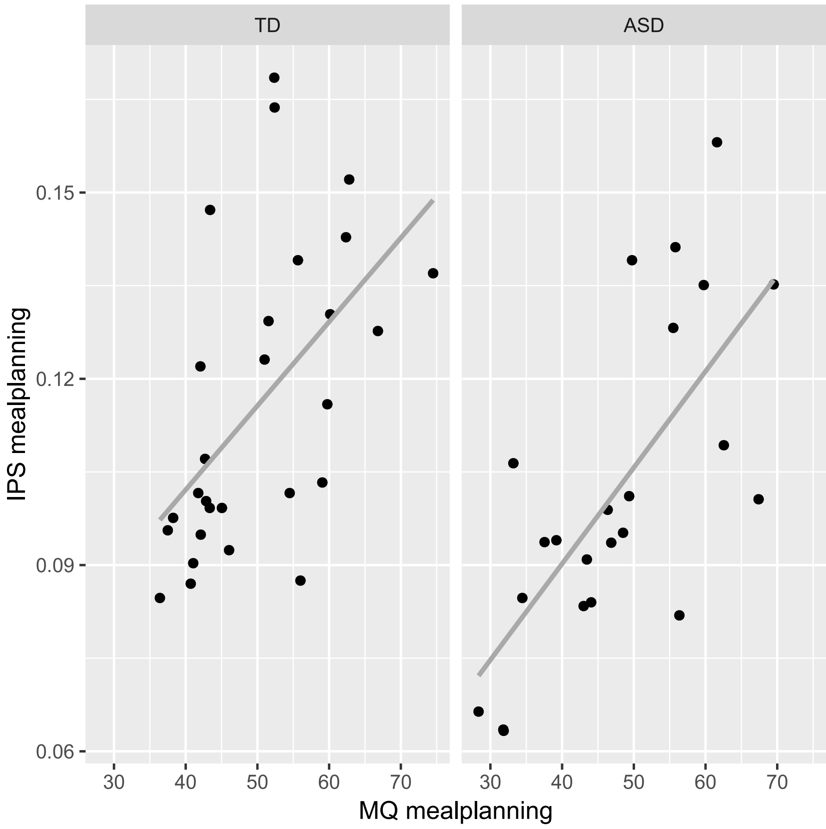
Note. *b* = beta coefficient. CI = confidence interval. Conditional R^2= 0.67.

Figure 7. Model 1.1 – Interpersonal Synchrony in Hobbies



Note. This figure provides an overview of the Model 1.1 variables interpersonal synchrony and movement quantity separately for each group (ASD and TD) in the task *hobbies*. It shows interpersonal synchrony (head ROI) as modulated by each dyad's movement quantity (head ROI) and the corresponding regression lines. A clear relationship between IPS and MQ is demonstrated for both groups.

Figure 8. Model 1.2 Interpersonal Synchrony in Meal Planning



Note. This figure provides an overview of the Model 1.2 variables interpersonal synchrony and movement quantity separately for each group (ASD and TD) in the task *meal planning*. It shows interpersonal synchrony (head ROI) as modulated by each dyad's movement quantity (head ROI) and the corresponding regression lines. A clear relationship between IPS and MQ is demonstrated for both groups. IPS is significantly higher in TD-TD dyads than in TD-ASD dyads in this task.

3.5 PERCEIVED SYNCHRONY (H1)

A linear mixed model was fitted to predict perceived synchrony with the diagnostic group, IPS (head ROI, after mean-centering), the interaction thereof, movement quantity (head ROI), and IQ as covariates (Table 5). For a visualization, see Figure 9. The model included confederates as a random effect. Looking at random effects, the intercept standard deviation (*SD* = 0.27) was smaller than the residual standard deviation (*SD* = 1.23). Consequently, the confederates did not explain much of the perceived synchrony variance. The model's total explanatory power was substantial (conditional R^2 = 0.29). With all other predictors held constant, perceived synchrony scores were estimated to be 1.23 units lower in the ASD than in the TD group. This effect was statistically significant (*b* = -1.23, CI = [-1.98, -0.49], *p* = .002). The effect of IPS on perceived synchrony was -0.2 in the ASD group and 14.8 in the TD group, while MQ and IQ were held constant; this effect was statistically non-significant (*b* = 14.8, CI = [-19.6, 49.1], *p* = .389). The effect of movement quantity on reported perceived synchrony while the other predictors were held constant was negative and statistically significant (*b* = -5.75e-02, CI = [-0.11, -6.38e-03], *p* = .029). The interaction effect of IPS and diagnostic group ASD on perceived synchrony while MQ and IQ were held constant was negative and statistically non-significant (*b* = -15.0, CI = [-52.7, 22.7], *p* = 0.425). The effect of IQ was statistically non-significant (*b* = -4.44e-03, CI = [-2.41e-02, 1.52e-02], *p* = .650).

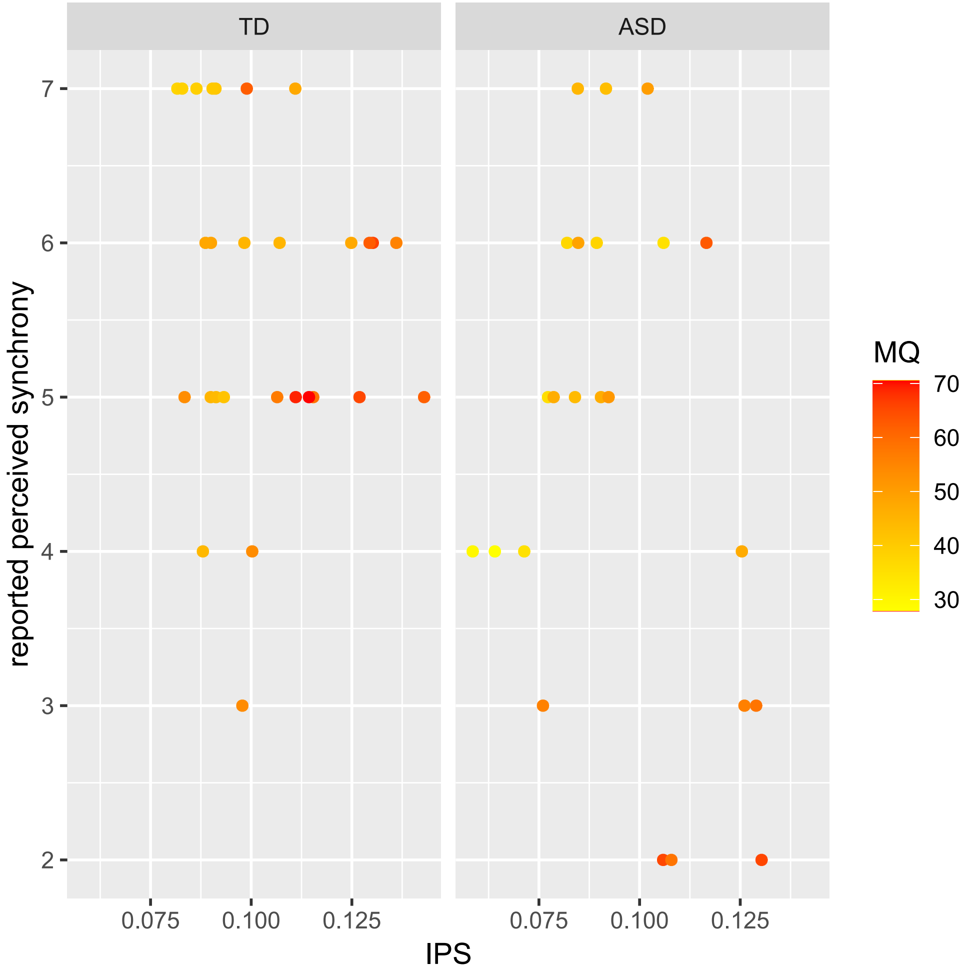
These findings demonstrate that the ASD group showed significantly reduced perceived synchrony, confirming hypothesis H1.1 of different synchrony perception between the groups. Additionally, movement quantity had a significant negative effect on the outcome variable. There was insufficient evidence to support hypothesis H1.2 that IPS modulates perceived synchrony in both groups.

Table 5. Model 2 - Perceived Synchrony

	b	95 % CI	*t*-value	*p*-value
Intercept	8.64	[6.08, 11.2]	6.83	<.001
Group ASD	-1.23	[-1.98, -0.49]	-3.36	.002
IPS	14.8	[-19.6, 49.1]	0.87	.389
MQ	-5.75e-02	[-0.11, -6.38e-03]	-2.28	.029
ASD:IPS	-15.0	[-52.7, 22.7]	-0.81	.425
IQ	-4.44e-03	[-2.41e-02, 1.52e-02]	-0.46	.650

Note. *b* = beta coefficient. CI = confidence interval. Conditional R^2= 0.29 The IPS values are mean-centered.

Figure 9. Model 2 - Perceived Synchrony



Note. This figure shows the participant's reported perceived synchrony scores as modulated by interpersonal synchrony (head ROI) for each dyad. The dots are color-coded according to the dyad's movement quantity (head ROI). Given that the LME model did not show a statistically significant effect, no regression lines are shown in this figure to prevent misdirected interpretation. As visualized in this figure, participants with ASD reported lower perceived synchrony than TD participants.

3.6 SOCIAL AFFILIATION (H2)

A linear mixed model was fitted to predict social affiliation with the diagnostic group, IPS (head ROI, after mean-centering), the interaction thereof, MQ (head ROI), and IQ as covariates (Table 6). For a visualization, see Figure 10. The model included confederates as a random effect. Looking at random effects, the intercept standard deviation (*SD* = 5.43e-05) was smaller than the residual standard deviation (*SD* = 0.83). Consequently, the confederates did not explain much of the social affiliation variance. The model's total explanatory power was weak (conditional R^2 = 0.08). With all other predictors held constant, the social affiliation scores were estimated to be 0.29 units lower for the ASD than the TD group. This effect was statistically non-significant (*b* = -0.29, CI = [-0.79, 0.21], *p* = .245). The effect of IPS on social affiliation, while MQ and IQ were held constant, was 10.1 in the ASD group and -2.64 in the TD group. This effect was statistically non-significant (*b* = -2.64, CI = [-25.0, 19.7], *p* = .812). The effect of MQ while the other predictors were held constant was negative and statistically non-significant (*b* =-6.56e-04, CI = [-3.40e-02, 3.27e-02], *p* = .968). The interaction effect of IPS and diagnostic group ASD on social affiliation while MQ and IQ were held constant was positive and statistically non-significant (*b* = 12.7, CI = [-12.6, 38.0], *p* = .315). The effect of IQ was statistically non-significant (*b* = -9.74e-03, CI = [-2.28e-02, 3.32e-03], *p* = .139).

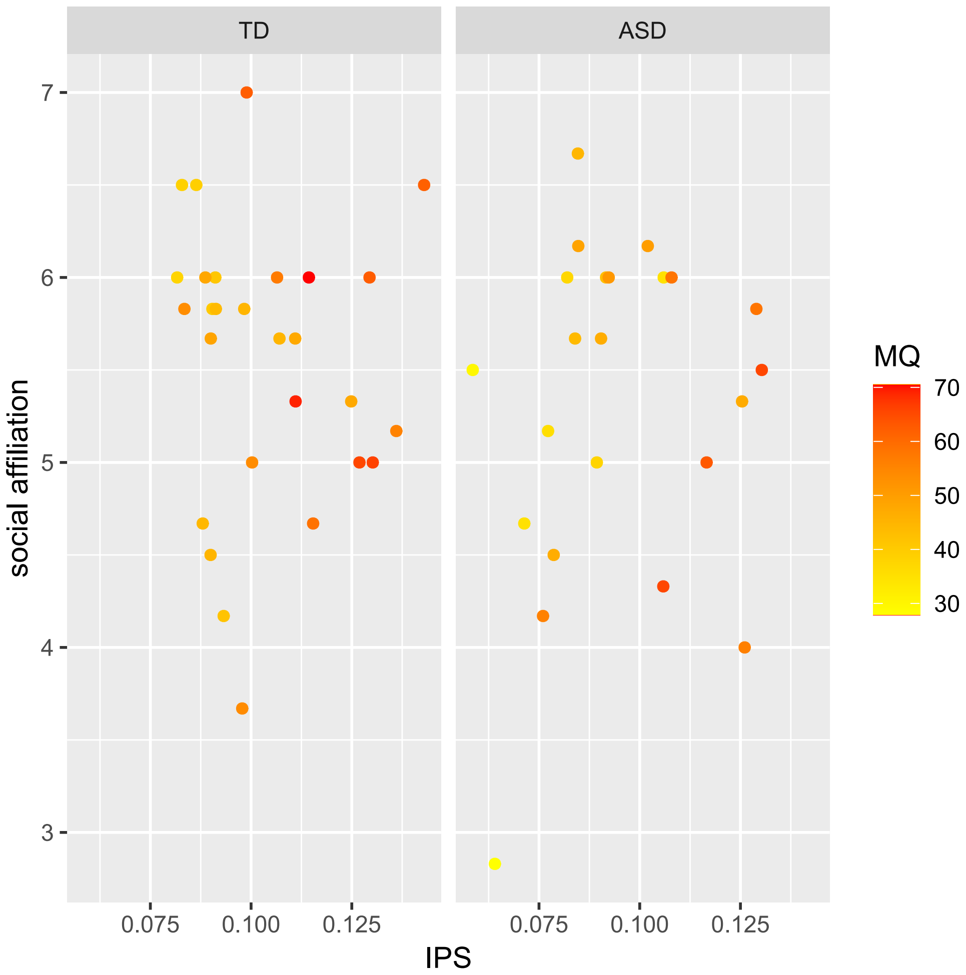
Therefore, the results reveal that neither the diagnostic group nor IPS could predict social affiliation when accounting for MQ and IQ, contradicting hypotheses H2.1 and H2.2. Also, the interaction between these two variables could not explain the observed variance in social affiliation scores. The variables entered in the model do not adequately predict social affiliation, which is in line with the small R^2 of the model.

Table 6. Model 3 - Social Affiliation

	b	95 % CI	*t*-value	*p*-value
Intercept	5.80	[4.12, 7.47]	7.04	<.001
Group ASD	-0.29	[-0.79, 0.21]	-1.18	.245
IPS	-2.64	[-25.0, 19.7]	-0.24	.812
MQ	-6.56e-04	[-3.40e-02, 3.27e-02]	-0.04	.968
ASD:IPS	12.7	[-12.6, 38.0]	1.02	.315
IQ	-9.74e-03	[-2.28e-02, 3.32e-03]	-1.51	.139

Note. b = beta coefficient. CI = confidence interval. Conditional R^2= 0.08. The IPS values are mean-centered.

Figure 10. Model 3 - Social Affiliation



Note. This figure shows the participant's social affiliation scores as modulated by interpersonal synchrony (head ROI) for each dyad. The dots are color-coded according to the dyad's movement quantity (head ROI). Both groups show similar distributions of social affiliation values. The figure demonstrates no clear relationship between IPS and social affiliation. This is in line with the LME model result, which shows no significant effect. Therefore, no regression lines are shown in this figure to prevent misdirected interpretation.

3.7 AFFECT (H3)

A linear mixed model was fitted to predict positive affect change over the *conversational task* with the diagnostic group, IPS (head ROI, after mean-centering), the interaction thereof, MQ (head ROI), and IQ as covariates (Table 7). For a visualization, see Figure 11. The model included confederates as a random effect. Looking at random effects, the intercept standard deviation (*SD* = 3.02e-05) was smaller than the residual standard deviation (*SD* = 0.44). Consequently, the confederates did not explain much of the positive affect change variance. The model's total explanatory power was moderate (conditional R^2 = 0.18). With all other predictors held constant, positive affect change was estimated to be 0.26 units lower in the ASD than in the TD group. This effect was statistically non-significant (*b* = -0.26, CI = [-0.53, 4.11e-03], *p* = .053). However, the *p*-value indicated a trend towards significance. The effect of IPS on the positive affect change was 9.3 in the ASD group and -6.67 in the TD group, while MQ and IQ were held constant; this effect was statistically non-significant (*b* = -6.67, CI = [-18.6, 5.30], *p* = .266). The effect of MQ while the other predictors were held constant was positive and statistically non-significant (*b* =1.71e-03, CI = [-1.61e-02, 1.95e-02], *p* = .847). The interaction effect of diagnostic group ASD and IPS on the positive affect change while MQ and IQ were held constant was positive and statistically significant (*b* = 16.0, CI = [2.50, 29.5], *p* = .022). The effect of IQ was statistically non-significant (*b* = -3.70e-03, CI = [-1.07e-02, 3.29e-03], *p* = .290).

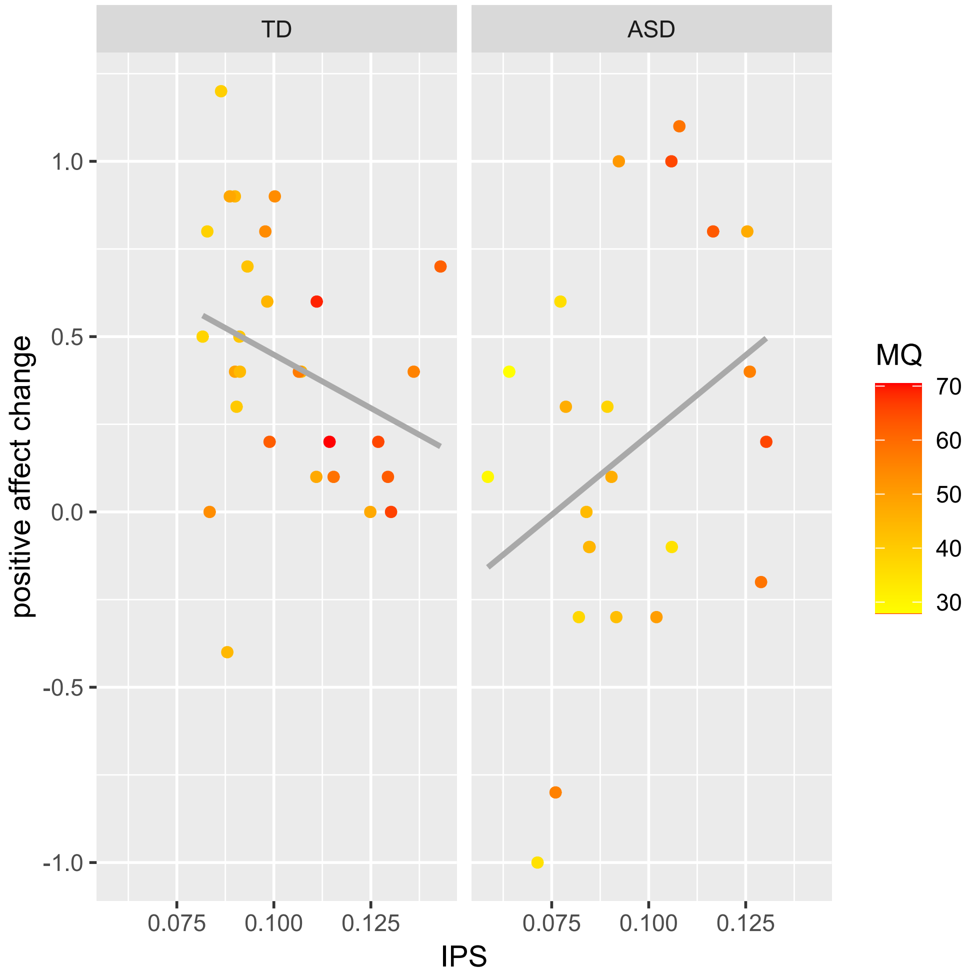
This finding demonstrates significantly different effects of IPS on the outcome variable positive affect change between the groups. For the TD group, increased IPS had a negative effect on the positive affect change, whereas, for the ASD group, increased IPS had a positive effect on the positive affect change. However, there was insufficient evidence to confirm hypothesis H3.2 that IPS modulates positive affect change. There was insufficient evidence to support hypothesis H3.1 that in the TD group, positive affect increases substantially more than in the ASD group. However, the inferred base-rate group difference (less positive affect change in the ASD group) trended towards statistical significance. Still, there was insufficient evidence to reject the null hypothesis.

Table 7. Model 4 - Positive Affect Change

	b	95 % CI	*t*-value	*p*-value
Intercept	0.44	[-0.45, 1.34]	1.00	.322
Group ASD	-0.26	[-0.53, 4.11e-03]	-2.00	.053
IPS	-6.67	[-18.6, 5.30]	-1.13	.266
MQ	1.71e-03	[-1.61e-02, 1.95e-02]	0.19	.847
ASD:IPS	16.0	[2.50, 29.5]	2.40	.022
IQ	-3.70e-03	[-1.07e-02, 3.29e-03]	-1.07	.290

Note. *b* = beta coefficient. CI = confidence interval. Conditional R^2= 0.18. The IPS values are mean-centered.

Figure 11. Model 4 - Positive Affect Change



Note. This figure shows the participant's positive affect change (change of PANAS scores over the *conversational task*) as modulated by interpersonal synchrony (head ROI) for each dyad. The dots are color-coded according to the dyad's movement quantity (head ROI). The regression lines show the estimated relationship between interpersonal synchrony and the positive affect change for both groups, assuming the movement quantity is the respective group average value. It should be considered that the LME model showed statistically significant differences in the slopes of the regression lines between the groups, while the absolute slope values were not statistically significant. This suggests that IPS differently modulates positive affect change between the groups, as this figure visualizes.

4. DISCUSSION

The following chapter interprets the findings, discusses the study's limitations, and integrates the results with previous findings in the literature.

4.1 SUMMARY MAIN RESULTS

In line with previous findings, the mixed dyads produced significantly less IPS than the TD group in the *meal planning* task, however, this was not the case in the *hobbies* task. With regards to the hypotheses, the diagnostic group interestingly demonstrated a significant predictive relationship with perceived synchrony, with the ASD group reporting less synchrony perception. Furthermore, results revealed similar levels of social affiliation in both groups. This study did not find statistically significant evidence for differences in affect change over the naturalistic conversation between the TD and ASD groups; however, a tendency of the ASD group to have a lower positive affect change is suggested. There was insufficient evidence of IPS' influence on social affiliation and perceived synchrony. However, there was a difference between the diagnostic groups in how IPS modulated positive affect change, emphasizing altered IPS processing and implications in ASD. Beyond this, the analyses revealed that movement quantity predicted IPS and perceived synchrony.

4.2 INTERPRETATION OF FINDINGS

4.2.1 PRODUCED INTERPERSONAL SYNCHRONY

When solely inspecting mean values of IPS, a difference between the diagnostic groups with lower IPS values for mixed dyads was captured in both subtasks, *hobbies,* and *meal planning*. Even though the mean differences appear marginal, they are comparable to the group difference observed in another recent study assessing IPS

(Koehler et al., 2021). When fitting the LME models for both subtasks separately and accounting for MQ and IQ, the diagnostic group did have a statistically significant effect on IPS in *meal planning* but not in *hobbies*. The result regarding reduced IPS in mixed dyads in the *meal planning* task is in line with previous research (Georgescu et al., 2020). The *hobbies* task is novel and might not be as sensitive to bring out differences in IPS between the dyad types since the task does not necessarily involve much turn-taking and, therefore, less communication skills. Participants can freely talk about their hobbies up to talking in monologues without the necessity to cooperate or continuously react to the conversational partner. In contrast, the *meal planning* task unavoidably requires bidirectional and constant communication, given that participants must agree on what food and drinks to choose. As a result, communication and interaction impairment present in individuals with ASD presumably emerge more apparently in the *meal planning* task, revealing significantly reduced IPS in dyads including an ASD participant, as replicated in this study.

The studies mentioned above did not control for MQ in their IPS analysis since they did not find a statistically significant difference between groups. In the present study, a divergent approach was chosen with MQ as a predictor variable to control for significant MQ differences between groups merely present in the *hobbies* task but not in the *meal planning* task. MQ had a statistically significant effect on IPS in both subtasks. The effects might appear marginal ($b_{hobbies}$ = 9.66e-04, $b_{mealplanning}$ = 1.49e-03), but considering the small IPS values and the relatively high variance in MQ, it can be considered a relevant effect. The model's high R^2 (conditional $R^2_{hobbies}$ = 0.44, conditional $R^2_{mealplanning}$ = 0.67) also support this claim, suggesting that the fitted models explained a large fraction of the observed IPS variance. Georgescu et al. (2020) did not find statistically significant differences in MQ between ASD-TD, TD-TD, and ASD-ASD dyads, which is in line with

Koehler et al. (2021). This study shows a similar result in the *meal planning* task, but a difference in MQ between the diagnostic groups was revealed in the *hobbies* task.

One consideration when comparing the studies might be that Koehler et al. (2021) had a control group comprised of participants with high autistic traits, where the ASD diagnosis was eventually ruled out. In this study, the TD group did not contain participants suspected of having ASD; wherefore, the comparability of the two control groups is restricted. Together, these findings highlight the necessity to further evaluate MQ in mixed (ASD-TD) and homogeneous dyads (TD-TD). Moreover, the aforementioned studies performed different statistical analyses (e.g., *t*-test or analysis of variance), while linear mixed-effects models were employed in this study. Withstanding the different statistical analyses, the contrasting nature of IPS between diagnostic groups in the *meal planning* task is consistent with other recent studies that found reduced IPS in ASD (Georgescu et al., 2020; Koehler et al., 2021). Given that the *meal planning* task produces consistent results across the literature, further investigation into the contextual dependency of IPS is warranted.

Unlike Georgescu et al. (2020), this project did not investigate IPS in the body and total ROI but solely in the head ROI (for an overview of the different ROI, see Appendix B). Due to COVID-19 restrictions, plexiglass was placed between the conversational partners. The plexiglass had a foil on it to prevent participants from seeing their reflections. However, this led to a potentially restricted vision of the partner. Together, the plexiglass and table made it difficult to see the partner's lower body (for quality check questions regarding this matter, see Appendix A). These circumstances differ from other studies assessing IPS in dyadic interactions. Another reason for comparable IPS between groups in the *hobbies* task might be due to limited power from the preliminary sample used in this analysis. The limited sample size might not have been large enough to detect relatively small differences in IPS between the dyadic groups.

Additionally, participants might feel uncomfortable talking to a stranger about rather personal topics, such as their hobbies[19], which might have impacted the results.

4.2.2 PERCEIVED SYNCHRONY

Results revealed that participants with ASD report less perceived synchrony, suggesting a different perception of synchrony. This finding emphasizes particular variation in how individuals with ASD might evaluate synchrony in interactive situations. To the best of knowledge, no other studies have investigated the subjective reported perception of synchrony during a dyadic social interaction including individuals with ASD, particularly from the perspective of the individuals with ASD. Therefore, this study may serve as groundwork in this regard, and future replication studies should further investigate this effect.

Surprisingly, MQ but not IPS showed a statistically significant effect on perceived synchrony, and the effect was negative. The lack of studies investigating MQ and reported synchrony perception in ASD make interpretation challenging. One explanation may be that participants interpreted the question about perceived synchrony[20] as referring to verbal rather than nonverbal communication. This possible focus on speech might explain this discrepancy between measured produced IPS and perceived synchrony. MQ might have negatively influenced perceived synchrony because participants could have perceived frequent and assumingly undirected movement (e.g., fidgeting) as disconnected from the conversation and, therefore, asynchronous. Another consideration is that the MQ measured in this project referred to dyadic MQ. Hence, it is theoretically possible that

[19] On a side note, it would be recommendable to assess how the conversational topic influences social affiliation and affect, given there might be exciting findings that could not be addressed in this study design.

[20] „Wie synchron war die Kommunikation zwischen Ihnen und Ihrem Partner?“ (“How synchronized was the communication between you and your partner?”)

confederates and participants moved a lot independently from each other, resulting in a perception of low synchronous behavior.

Divergent perception of synchrony presumably has an important impact on the quality of interactions, which might contribute to the widely observed interactive challenges among individuals with ASD. Hence, research focusing on this relevant perceptual aspect of interactions is beneficial in advancing the understanding of varying interactive behavior in individuals with ASD.

4.2.3 SOCIAL AFFILIATION

Interestingly and contrary to expectations, neither the diagnostic group nor IPS predicted social affiliation. This finding demonstrates that social affiliation is similarly distinct in this specific interactional context in participants with ASD as in TD participants. This finding is somewhat surprising, given that individuals with ASD struggle with interaction difficulties and are perceived as less socially engaged (AWMF, 2016; Chevallier et al., 2012). When evaluating the presented results against the background of other studies, this is inconsistent with Morrison et al. (2019), who found that participants with ASD felt closer to their partners than TD participants after an unstructured conversation, contradicting evidence of decreased social motivation in ASD (Chevallier et al., 2012). Morrison et al. (2019) postulate that individuals with ASD may feel even more social affiliation because social interactions are less frequent for them. The divergent results from the present study may lie in the fact that Morrison et al. (2019) did not explicitly assess social affiliation with the same questionnaires used in this study but instead used different instruments measuring subjective closeness. Other studies which revealed a positive relationship between synchrony and social affiliation did not exclusively refer to IPS measured by MEA (e.g., Hove & Risen, 2009). Instead, they referred to synchronous processes (e.g., matching hand movements with a metronome rhythm; Hove & Risen, 2009) or conscious synchronous motion (e.g., dancing synchronously; Tarr et al., 2016). Therefore, there seems to be high diversity in the methods used to assess such variables, and further work is needed to comparatively assess such measures.

Results suggest that the measured variables did not adequately explain the variance in the outcome variable. However, in this specific context, one could argue that a small R^2 is not surprising, given that numerous factors likely influence social affiliation, which may be measured in various ways. It is unknown how much participants from this study enjoyed or opposed social interactions in general. This basic attitude toward social interactions might be essential in predicting social affiliation and affect. Thus, it may be helpful to assess and account for the extent to which participants generally enjoy engaging in social interactions.

Another relevant factor might be the prior knowledge of the confederates regarding ASD. This study's confederates mainly worked in research, psychology, and medicine. Thus, they had some basic knowledge about ASD and were aware they might encounter a participant with ASD at some point. Even though they were not informed about the diagnoses of their conversational partner, they may have modified their behavior to cater to the participant, possibly resulting in overcompensation. Matching the confederate and participant for gender and age was impossible in this project, occasionally leading to increasingly heterogeneous dyads. This condition may have contributed as a skewing factor. Also, it should be mentioned that all experiments happened during the coronavirus disease 2019 (COVID-19) pandemic, which might have influenced how participants perceive and value social interactions and conversations in general. Even though the data collection did not occur during a lockdown, this exceptional situation most likely affected participants' social affiliation abilities and affect.

Nonetheless, it appears social affiliation can be similarly facilitated for TD and ASD individuals when the social interaction is pleasant and accompanied by respectful communication. This provides novel insight into bonding behavior and may contribute to a decrease in stigmatization, given that social affiliation is equally present in individuals with ASD in the tested sample.

4.2.4 AFFECT

Participants with ASD showed a smaller increase in positive affect than their TD counterparts; this effect trended towards statistical significance. This finding may be explained by interaction difficulties observed in individuals with ASD, resulting in more stressful social interactions and diminishing the enhancement of positive emotions. Results from this study indicate that IPS did not significantly predict positive affect change. These results contrast with findings from other studies, which captured that *inter*personal synchrony predicted an increase in positive affect (Galbusera et al., 2019; Tschacher et al., 2014). This discrepancy may be explained by using different methods. Galbusera et al. (2019) implemented a task about whole-body movement improvisation between two interaction partners and analyzed it with novel behavioral imaging technology. Hence, they excluded verbal communication from the task and did not use MEA for analysis purposes. Contrary to this study, their sample exclusively included TD participants between 20 and 35 years. They also added a measurement of *intra*personal synchrony in their model. They found it predicted a decrease in positive affect, while *inter*personal synchrony predicted an increase in positive affect. Tschacher et al. (2014) only used same-sex TD dyads (to prevent interaction complications) in a conversational setting consisting of 5 topics. They used MEA for video analysis; however, their models did not control for MQ.

Whereas merely IPS was not found to predict the positive affect change in this study, there was a substantial difference between groups in how IPS influenced positive affect change. This intriguing new finding can be interpreted as different underlying processing of IPS between participants with and without ASD. Furthermore, nearly all participants with TD reported increased positive affect, while this varied more strongly for participants with ASD. A factor to consider is that individuals with ASD are likely to struggle to recognize their emotions (Hill et al., 2004). Consequently, the answers given by participants with ASD in the PANAS and social affiliation questionnaire might not reflect the participant's genuine emotion. In contrast to studies assessing TD participants solely, it remains uncertain whether the questionnaire answers in this ASD sample were fully reliable.

The apparent but non-significant decrease of positive affect change with the increase of IPS in the TD group was surprising. A ceiling effect may explain this, given that participants reporting high positive affect before the task might not experience as much of an increase in their positive affect as participants having a relatively low positive affect before the task. This is supported by the observation that higher positive affect before the task correlated with smaller positive affect changes over the task (see Appendix B). Speculatively, TD participants who were already in a good mood before the task contributed to high IPS in the dyad, but their positive affect did not increase as much due to a possible ceiling effect. Taken together, this study provides novel evidence of altered IPS impact on emotions in individuals with ASD. Throughout a dyadic conversation, the positive affect appeared to increase less for individuals with ASD. To gain higher certainty, it is necessary to investigate this effect in a larger sample with more statistical power.

4.3 LIMITATIONS

Regarding the measured sample (n = 52), there are apparent differences in the questionnaires assessing auistic traits (e.g., AQ) between the diagnostic groups (n_{ASD} = 23, n_{TD} = 28). Therefore, it can be assumed that the intended different group compositions have been achieved through appropriate recruitment and that the groups can be clearly distinguished from one another. However, it is possible that only individuals who were either confident about their interactive qualities or looking for training in that regard agreed to participate in the study, given that study participation involved stepping out of their comfort zone and engaging in a conversation with a stranger. Either way, the participants with ASD from this sample are likely a relatively social and rather high-functioning subgroup within the Autism Spectrum. This study focused on people between 18 and 60 years with an IQ above 70. Only with a much larger sample size could a broader Spectrum be evaluated with sufficient scientific precision, including children, the elderly, and individuals with intellectual disabilities. Since MRI tasks were part of the extensive study, only individuals fitting the numerous MRI inclusion criteria (e.g., no strong noise sensitivity or claustrophobia) agreed to participate, leading to a smaller subgroup of the Spectrum. Additionally, the sample only involved six female participants with ASD (10 female TD participants).

Another factor that might bias the results is that 12 participants with ASD reported having a comorbid psychiatric disorder, and 14 took psychotropic medication, which can influence social interactions (Georgescu et al., 2020; Girard et al., 2014). This constellation likely also contributed to the tendency that the ASD group moved less frequently in this sample. It has been observed that in patients with depression, movement quantity is less distinct (Paulick et al., 2018). Furthermore, the preliminary sample's relatively small size is notable, which might be too limited to detect slight differences between groups. When interpreting the results, these limitations regarding the assessed participant collective should be considered.

There are some specific strengths and limitations to the questionnaires used in this study. The questionnaire for affect assessment (PANAS) was selected because it was used for reliable affect assessment in numerous studies, even in conjunction with synchrony assessment (Tschacher et al., 2014). However, the participants had to fill out the PANAS twice within 25 minutes. This redundancy might have biased the answers. The questions regarding social affiliation and perceived synchrony were utilized in a study investigating IPS before (Cacioppo et al., 2014). Nonetheless, this questionnaire is a relatively novel instrument with little prior study use and had to be translated to German for this study (see Appendix C); therefore, the validity and reliability remain to be confirmed. Moreover, it must be considered that reported perceived synchrony was measured by one single question. For some participants, the question assessing perceived synchrony was not easily understandable, leading to requests for clarity. It remained unclear whether the question targeted synchronous verbal communication or synchronous nonverbal communication. Without proper validation, the question's meaning might have been difficult to understand in German, possibly resulting in misled interpretations. Taken together, this might limit the informative value of the results regarding this question.

In line with recent studies assessing IPS in ASD (Georgescu et al., 2020; Koehler et al., 2021), the well-established and reliable tool MEA was used for video analysis (Fujiwara et al., 2021; Ramseyer & Tschacher, 2008; Ramseyer & Tschacher, 2011; Ramseyer, 2020). Various efforts have been made to facilitate and simplify video analysis of interpersonal nonverbal synchrony and objectively quantify synchrony (Paxton & Dale, 2013). Before frame-differencing methods, IPS was rated by judges or observers and resulted in subjective impressions (Bernieri et al., 1994). By implementing (semi-) automated methods such as MEA (Ramseyer & Tschacher, 2011), the ability to objectively assess IPS has largely risen (Schmidt et al., 2012). Compared with manual coding, automated methods have the advantage of being less time-consuming but provide similar results (Fujiwara et al., 2021). Generalizability, reproducibility, and objectivity are integral components of reliable video analysis. Consequently, the objective investigation of synchrony with methods such as MEA mostly overtook subjective methods. Thus, MEA has been commonly used in several recent studies (Georgescu et al., 2019; Georgescu et al., 2020; Noel et al., 2018; Tschacher et al., 2014).

Nevertheless, MEA has some limitations, including its inability to account for region-crossing. When a participant touches their face, their hand from the body region (ROI II) moves into their head region (ROI I), resulting in additional noise for the head ROI. Another limitation is that MEA does not assess qualitative domains of nonverbal behavior, such as accepting or rejecting facial expressions (Tschacher et al., 2014). Even though MEA is considered a reliable tool to measure IPS, more advanced imaging approaches have been proposed because they offer a higher resolution of nonverbal behavior recognition (Galbusera et al., 2019). Further data processing was conducted by applying cross-correlation analysis in rMEA and summarizing the outputs into a mean IPS value for each dyadic interaction (for details, see Kleinbub & Ramseyer, 2021). It should be considered that this simplifies IPS across a lengthy conversation (approximately 20 minutes in total). Naturally, such aggregation does not capture an in-depth picture of how IPS occurred across the interaction regarding qualitative dimensions but instead gives a simplified average rate of IPS. Despite being commonly used in this way (for example, Ramseyer & Tschacher, 2011; Tschacher et al., 2014; Georgescu et al., 2020; Koehler et al., 2021), future investigations may consider more robust methods of aggregation.

Furthermore, this study used LME modeling to account for random and several fixed effects. It is a powerful statistical tool and adequate for the specific hypotheses analyzed in this study. The number of covariates was kept limited to receive an informative output in the LME models and prevent overfitting. However, various additional factors might have influenced the outcome variables, such as autistic traits (scores in AQ), coordination difficulties (scores in ADC), participation in former studies with a similar task, presence of psychiatric disorders or psychotropic medication, gender, and matching with the confederate in respect of age, gender, or mutual interests. Including the provided additional factors might increase the explanatory power and may be considered in future studies if possible.

4.4 IMPLICATIONS FOR FUTURE RESEARCH

The findings demonstrating differences in synchrony perception in dyadic interactions raise the necessity to evaluate perceptual aspects further. To gain advanced knowledge, different dimensions of perception may be assessed. In this study, participants reported how they perceived synchrony during their conversation. Given that perception is comprised of various dimensions, future research may expand on this study and behaviorally examine perception using more extensive and thorough questionnaires. Beyond that, it would be highly beneficial to measure perceptual aspects more objectively, for example, by taking neural correlates of synchrony perception into account (also see the overarching project; Nelson et al., in prep.). This may lead to a more integrative and holistic picture of perception during interactions in individuals with ASD.

In this project, a link between MQ and IPS has been disclosed. The role of MQ in naturalistic interactions and its influence on other nonverbal behavior such as IPS is not yet fully understood. Recent research argued that it might impact IPS as a confounding factor (Georgescu et al., 2020; Koehler et al., 2021). The present study provides evidence that MQ has a positive relationship with IPS using LME models. Furthermore, a strong correlation between MQ and IPS was captured. The lack of fundamental knowledge regarding the role of MQ when investigating IPS in dyadic social interactions makes interpretation challenging. Based on the novel findings of this study, further research can aim for a more fundamental understanding of MQ, its underlying mechanisms, and subsequent effects. Further research is needed to investigate the extent to which MQ interferes or interacts with IPS to achieve a more precise understanding of these observations. On the one hand, MQ may capture when participants feel nervous or uncomfortable (e.g., fidgeting). On the other hand, it might represent a lively and pleasant conversation, typically leading to enhanced IPS. Given this uncertainty, future fundamental research should investigate MQ concerning IPS and its qualitative and quantitative role in dyadic interactions.

This study assessed the behavioral and emotional patterns of a specific subgroup of individuals with ASD. Future approaches may expand the claims provided by this study and investigate other subgroups of the Spectrum regarding social affiliation and affect in dyadic conversations. Moreover, it might be advantageous for future studies to recruit more neutral TD participants rather than confederates as interaction partners, as this approach might prevent possible overcompensation during the conversations. It would also be interesting to assess the confederates' social affiliation and affect, in which this insight would help better understand the dyadic relationship established during the task.

Moreover, future research may further investigate the influence of conversation topics on IPS separately and assess IPS differences in other regions of interest, such as the body region, to include hand gestures. It may also be beneficial to explore methods of measuring IPS that provide a more detailed picture over time. For example, IPS production might be very low at the rather uncomfortable beginning of a conversation between strangers and might increase over time. Progression in capturing IPS dynamics over time and extending the qualitative aspects is most relevant to advance IPS analysis.

4.5 CONCLUSION

Social interaction difficulties are highly prevalent in ASD and can significantly impact one's quality of life (AWMF, 2016). Given their vast implications, recent efforts have aimed to identify variations in nonverbal behavior and IPS in individuals with ASD (e.g., Georgescu et al., 2020; Noel et al., 2018; for a review, see McNaughton & Redcay, 2020). This study explored perceptual and behavioral patterns in individuals with ASD compared to TD individuals during social interaction. Specifically, this study investigated interpersonal and perceived synchrony, social affiliation, and positive affect in a dyadic conversation. Differences were captured in the reported synchrony perception, exhibiting altered synchrony processing in ASD. This finding points toward a possible reason for altered behavior and social interaction difficulties in individuals with ASD. Future studies may include other dimensions of synchrony perception, such as neural correlates. To prospectively aim for specific intervention and support for individuals with ASD struggling with social interactions, further research on synchrony perception and its influence on behavior is warranted.

The present study provides new information about social interactions in individuals with ASD. Despite documented interaction difficulties in ASD, a similar extent of social affiliation after a naturalistic dyadic conversation in the ASD and TD groups was found. Data suggests the positive affect increases less in the ASD group over the conversation; however, a larger sample is needed to confirm this effect conclusively. These findings further knowledge about bonding behavior and emotions in individuals with ASD. Replicating prior research, significantly reduced IPS in the ASD-TD dyads was found in the *meal planning* task. For future studies, it might be beneficial to develop methods that take into account the evolution of IPS during conversations, enabling a more fine-grained analysis. The present analysis revealed movement quantity as a relevant influencing factor of IPS, emphasizing the requirement to further investigate the effects of MQ in dyadic interactions. IPS modulated affect differently in the two groups, displaying disparities between the ASD and TD groups in how IPS influences the emotional domain. Taken together, this study offers novel insights into the perceptual and behavioral patterns and inner emotional processes of social interactions in individuals with ASD. Future studies may continue exploring these aspects to ensure a more profound understanding of the complex mechanisms involved in social interactions and their presentation in individuals with ASD.

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APPENDICES

APPENDIX A: TABLES

Table 8. Positive and Negative Affect

	ASD Mean (SD)	TD Mean (SD)
Positive affect before	2.72 (0.77)	3.04 (0.64)
Positive affect after	2.89 (0.82)	3.46 (0.65)
Negative affect before	1.64 (0.62)	1.35 (0.53)
Negative affect after	1.48 (0.50)	1.22 (0.52)

Note. Assessed using the PANAS before and after the *conversational task*. 5-point Likert scale (1 = "not at all", 5 = "extremely"). Group mean and standard deviation.

Table 9. Psychiatric Disorders and Medication

	Participants with ASD
Comorbid psychiatric disorders	12
Psychotropic medication (one or more)	14
Antidepressants	8
Antipsychotics	6
Other	3

Note. This table shows the number of participants with ASD who reported comorbid psychiatric disorders or psychotropic medication intake. Psychotropic medication was not an exclusion criterion for the ASD group because many interested individuals with ASD took some psychotropic medication to treat psychiatric comorbidities. It was vital to include this group to reach a sufficient sample size. The total number of ASD participants assessed in this study was n = 23.

Table 10. Quality Check of Experimental Setup

	ASD	TD
	Mean (SD)	Mean (SD)
"How much did the video recording influence your behavior?"	0.43 (0.51)	0.50 (0.58)
"How much did the plexiglass influence your behavior?"	0.57 (0.51)	0.86 (0.76)

Note. Questions for quality checks after the *conversational task* (scale 0 - 3, 0 = "not at all", 1 = "a little bit", 2 = "quite", 3 = "very much"). Group mean and standard deviation.

Table 11. Inclusion Criteria

	ASD	TD
Diagnosis of Autism Spectrum Disorder as per the ICD-10 and according to the German S3-guidelines (AWMF, 2016)	x	
Age between 18 and 60	x	x
Normal or corrected-to-normal vision	x	x
No psychiatric diagnoses		x
No neurological diagnoses	x	x
No psychiatric medication		x
IQ > 70	x	x
Written informed consent of study participation	x	x
No magnetic metal implants (because of MRI)	x	x
No Claustrophobia (because of MRI)	x	x
No pregnancy (because of MRI)	x	x

APPENDIX B: FIGURES

Figure 12. Study Protocol

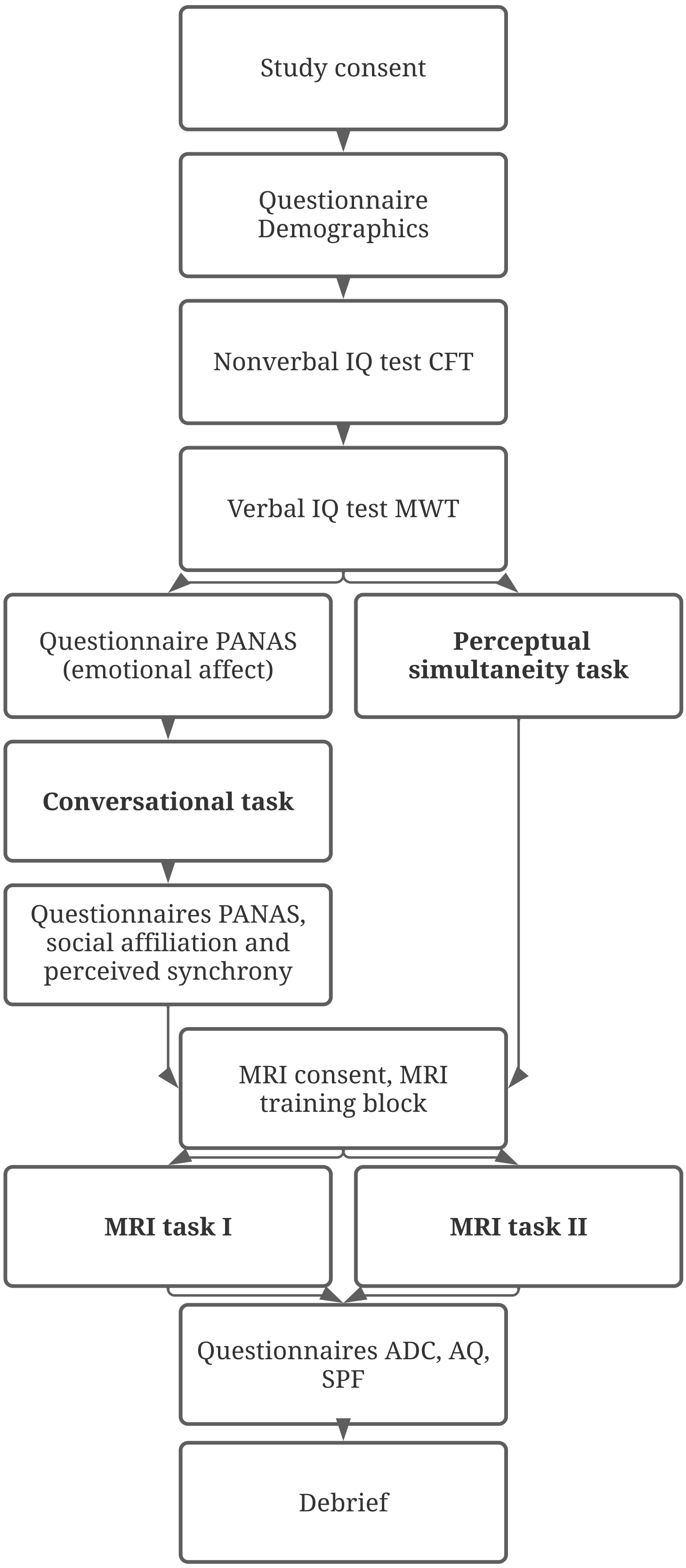
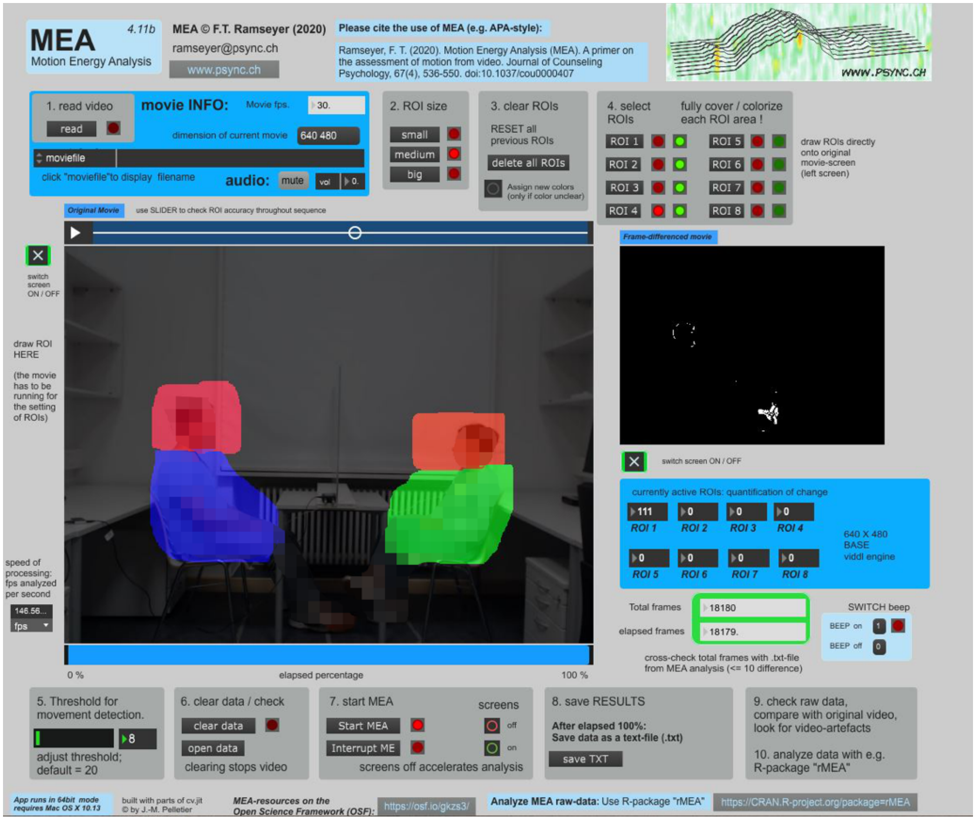
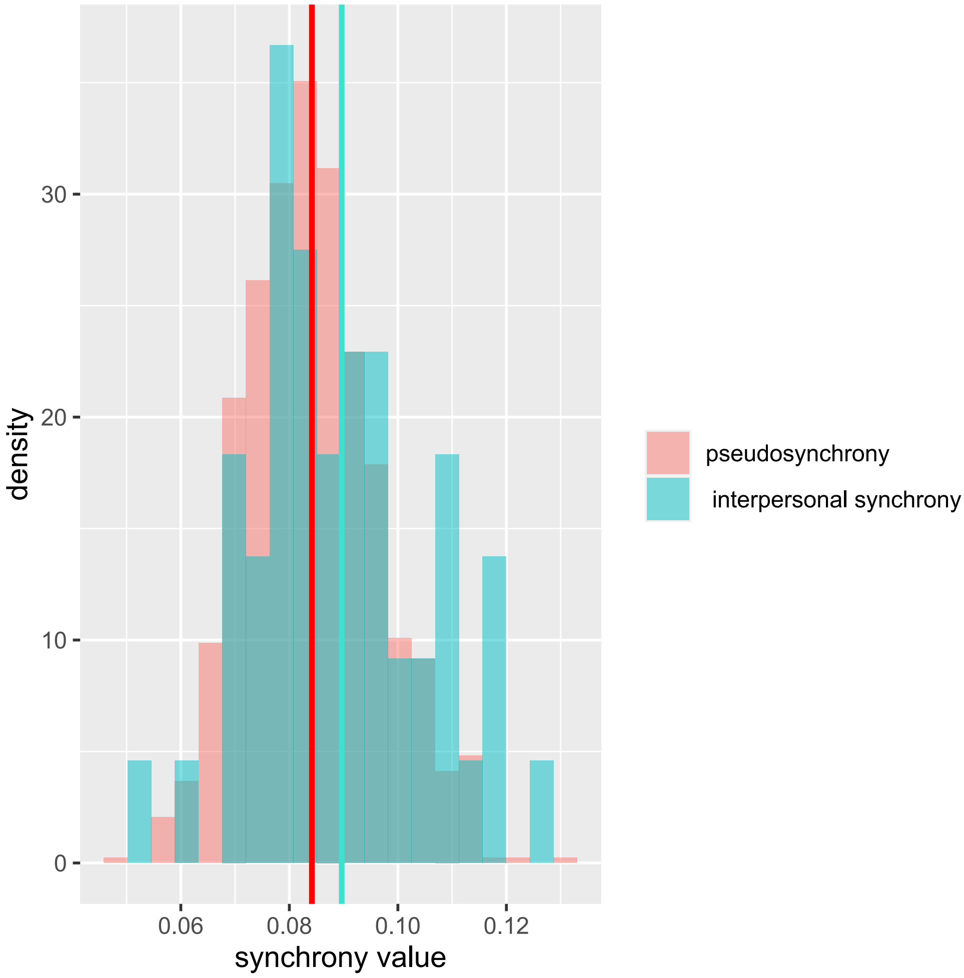


Figure 13. Example MEA



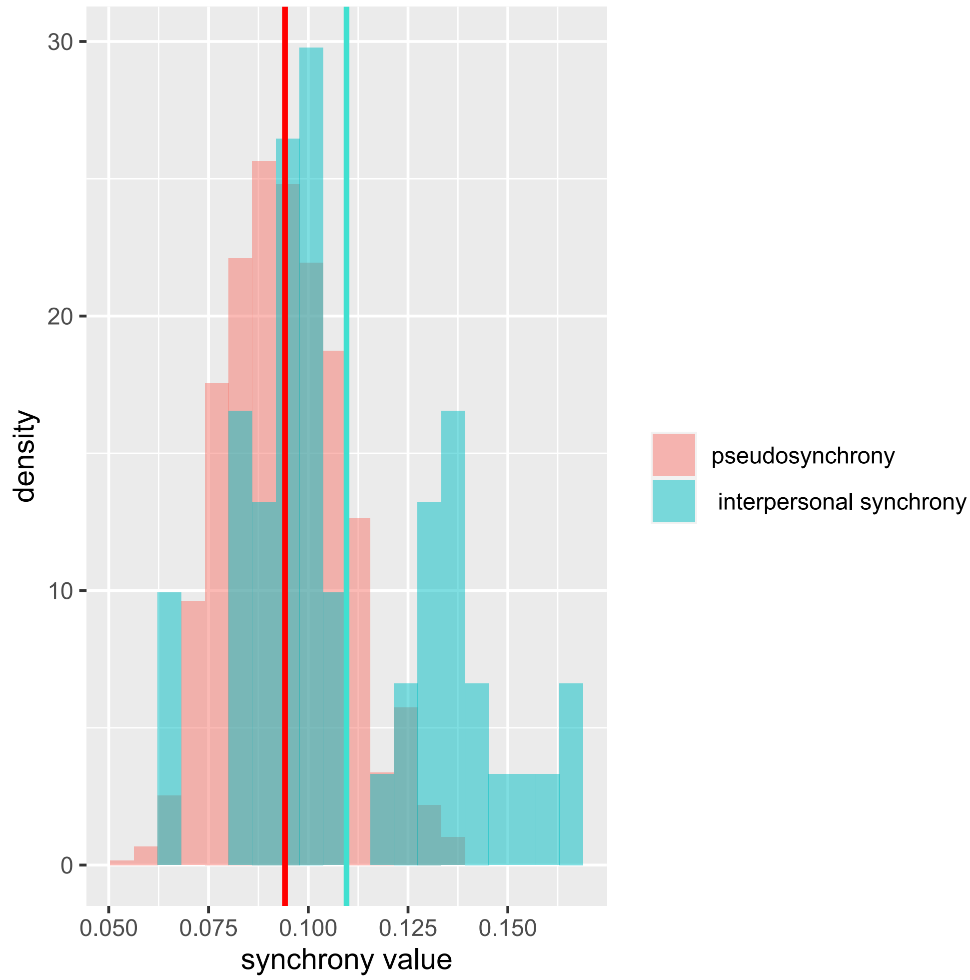
Note. Example of the user interface from Motion Energy Analysis (Ramseyer, 2020). In the middle, the read-in video is shown with the anonymized participant and confederate from a dyadic interaction during the *conversational task*. Step 1-10 explain the steps needed to extract the motion energy from the video. Under step 5., the threshold used in this study can be seen. The colors represent the different Regions of Interest (ROI): Participants' head is ROI I (in this example, red), participants' body ROI II (blue), confederates' head ROIII (orange), and confederates' body ROI IV (green). On the right, the total video frames are presented. Each video contained 18.180 frames in this study.

Figure 14. Pseudosynchrony and IPS in Hobbies



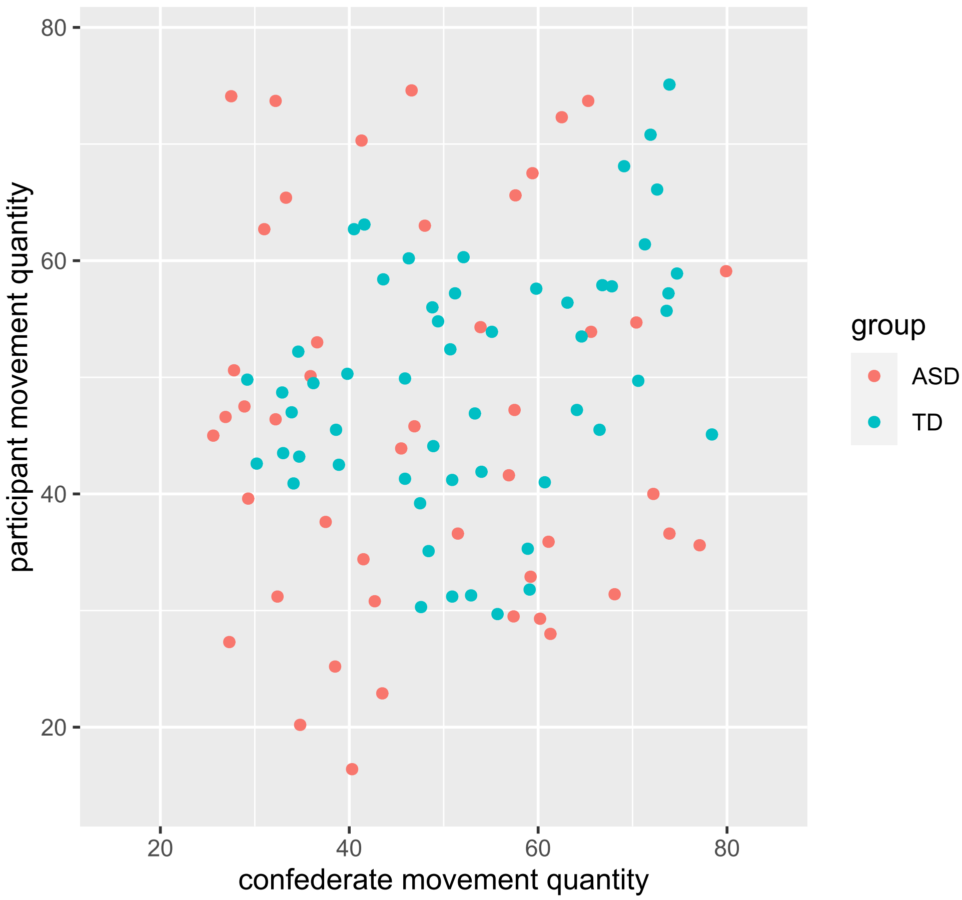
Note. Density plot for all observed synchrony values in the task *hobbies*. The vertical lines represent the means for interpersonal synchrony (turquoise, n = 50) and pseudosynchrony (red, n = 1000) values. This visually illustrates that in the task *hobbies* IPS values assessed in this sample exceed pseudosynchrony values.

Figure 15. Pseudosynchrony and IPS in Meal Planning



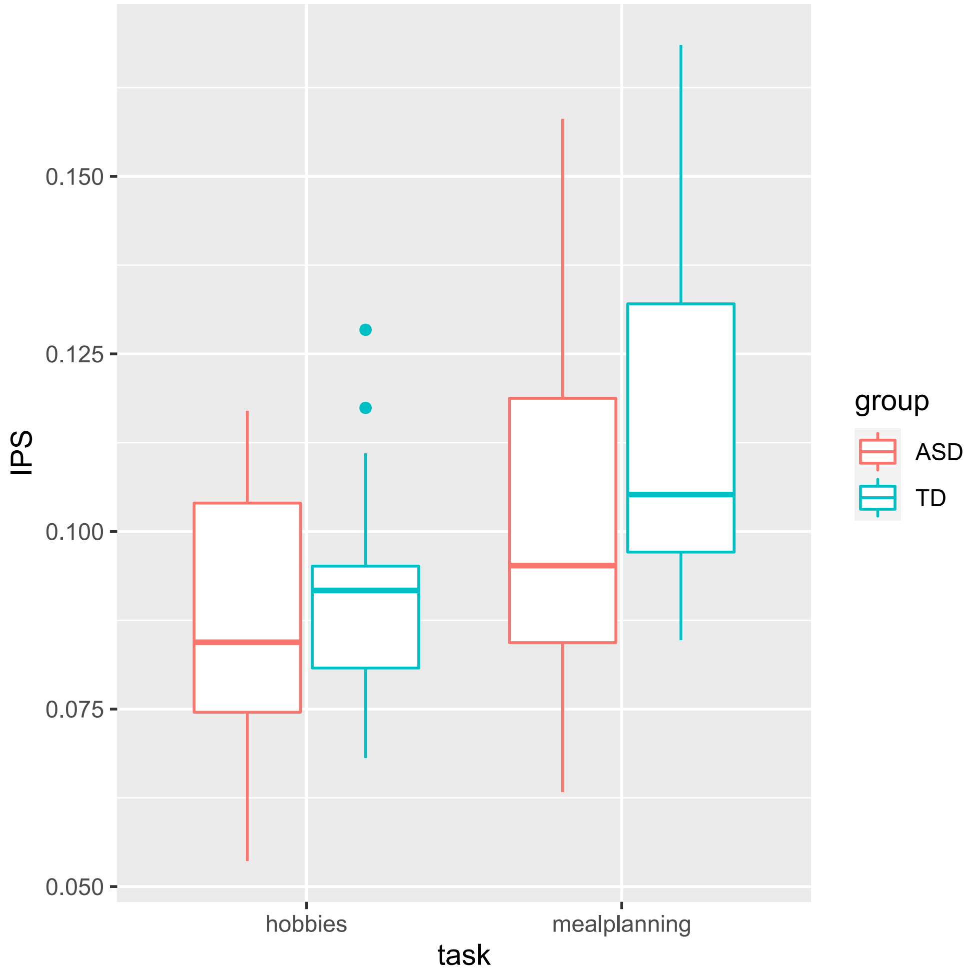
Note. Density plot for all observed synchrony values in the task *meal planning*. The vertical lines represent the means for interpersonal synchrony (turquoise, n = 51) and pseudosynchrony (red, n = 1000) values. This visually illustrates that in the task *meal planning* IPS values assessed in this sample exceed pseudosynchrony values.

Figure 16. Movement Quantity



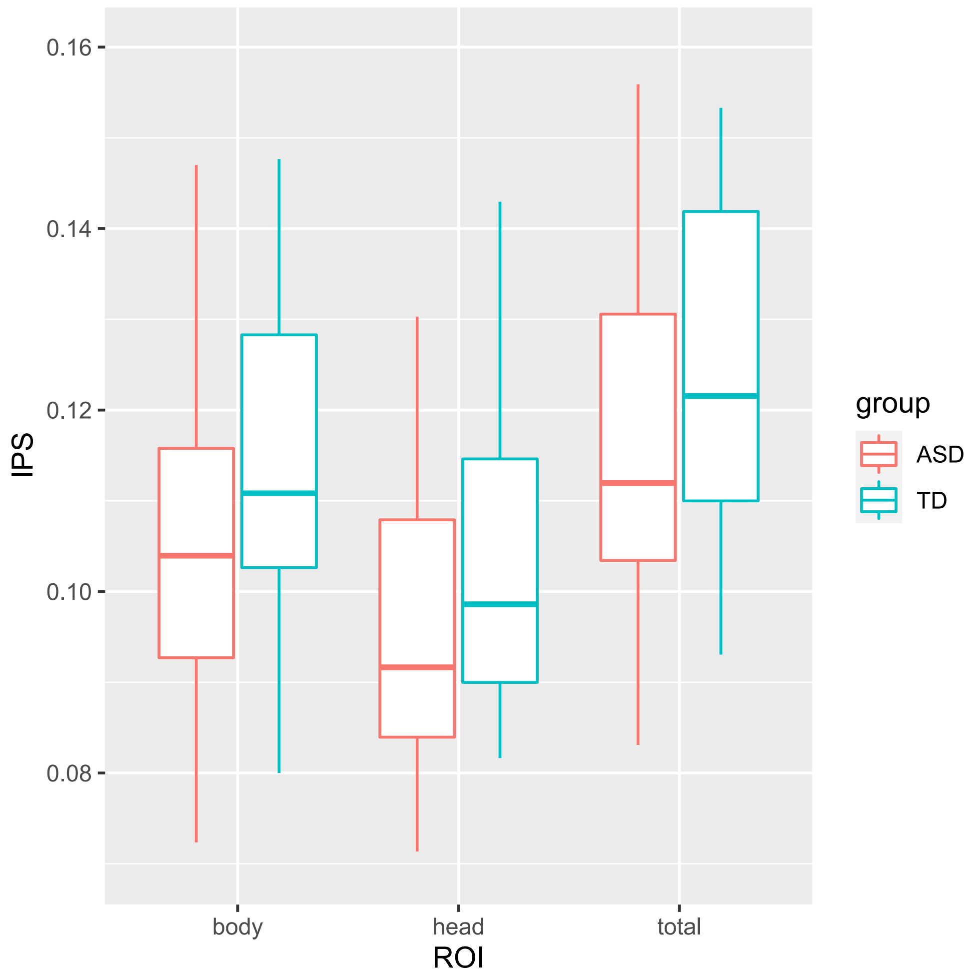
Note. This figure shows the movement quantity (head ROI) from each dyad: participants' MQ as modulated by confederates' MQ. Group explains whether the participant was an ASD or TD participant; the confederates were always TD, leading to mixed (ASD-TD, red) or homogeneous (TD-TD, turquoise) dyads. This figure shows no strong relationship between confederates' and participants' MQ. Additionally, mixed (ASD-TD, red) dyads demonstrate a more extensive range of MQ values.

Figure 17. Interpersonal Synchrony in Hobbies and Meal Planning



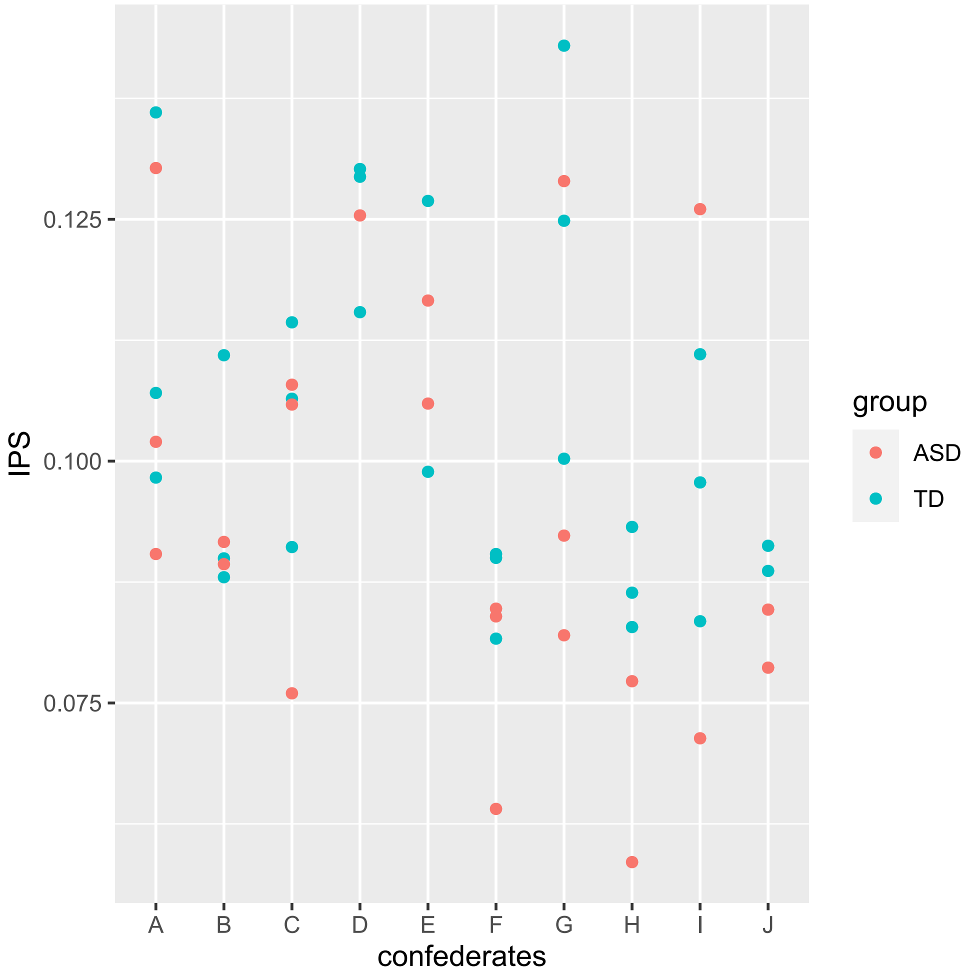
Note. This box plot shows interpersonal synchrony values for both groups (ASD red, TD turquoise) for the two topics discussed during the *conversational task*. Both subtasks (*hobbies* and *meal planning*) were combined for the analysis of this project. As can be seen in this figure, IPS was higher in the subtask *meal planning* for both groups.

Figure 18. Interpersonal Synchrony in different Regions of Interest



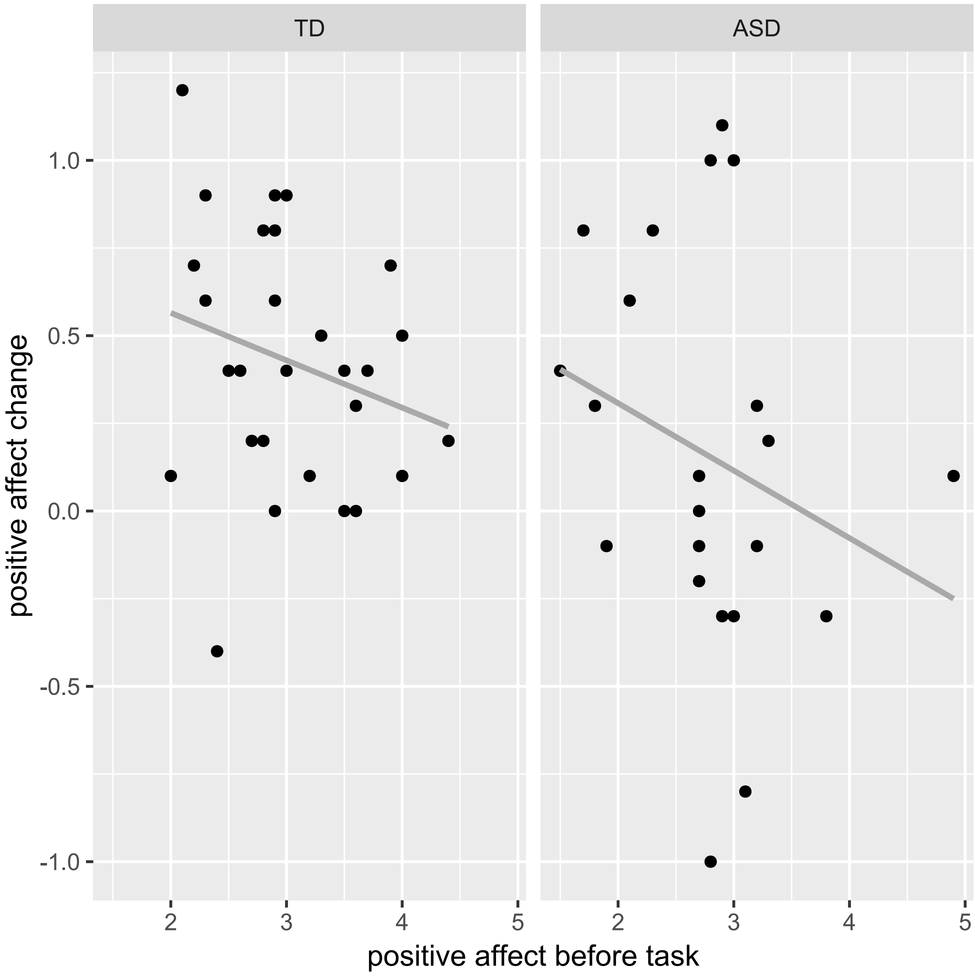
Note. This figure presents the interpersonal synchrony produced in the body region of interest (ROI), the head ROI, and the total ROI during the *conversational task* for both groups separately. This figure points out that IPS values differ between the three ROI and that IPS was higher in the TD group in every ROI.

Figure 19. Interpersonal Synchrony and Confederates



Note. This figure presents each confederate (A-J, n = 10) and the interpersonal synchrony produced in each of their dyadic interactions. Each confederate interacted with between four and six participants. Group refers to the participants (n = 51) diagnostic group. Confederates were all TD, leading to mixed (ASD-TD) and homogeneous (TD-TD) dyadic interactions. The figure shows variation in IPS values between the different confederates.

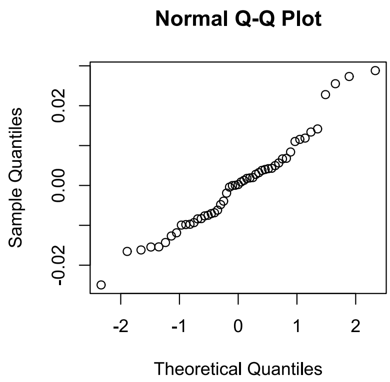
Figure 20. Positive Affect



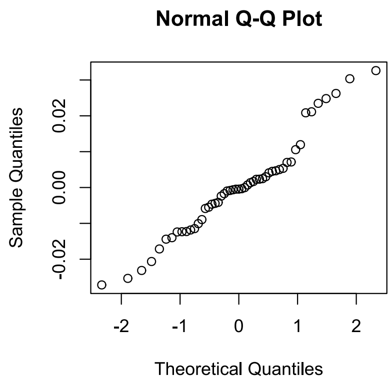
Note. This figure shows the positive affect change over the *conversational task* as modulated by positive affect measured before the task and the corresponding regression lines. Affect was assessed using the PANAS (Watson et al., 1988). This figure presents a clear negative relationship between positive affect before the task and the positive affect change in both groups.

Figure 21. Q-Q Plots to Check Normality

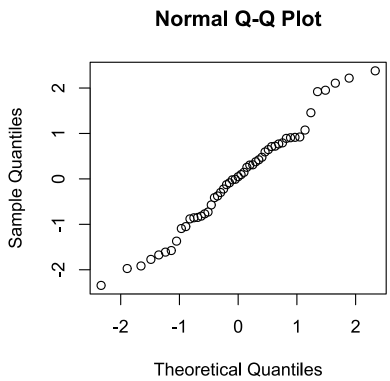
Model 1.1: IPS hobbies



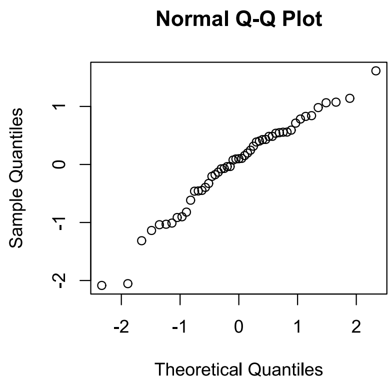
Model 1.2: IPS meal planning



Model 2: Perceived synchrony



Model 3: Social affiliation



Model 4: Positive affect change

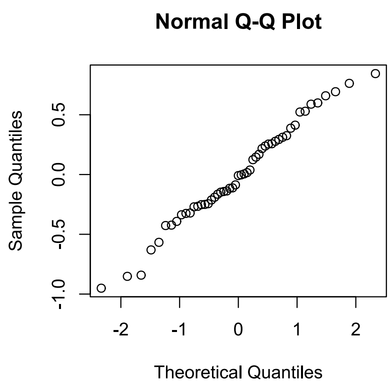
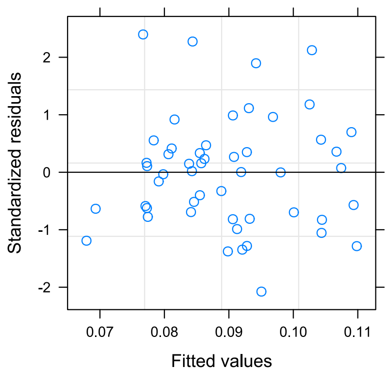
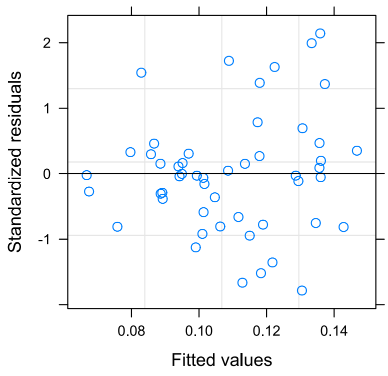


Figure 22. Residual Plots to Check Homoscedasticity

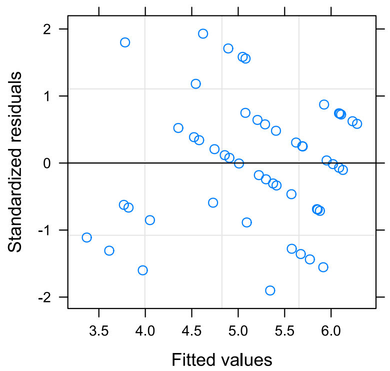
Model 1.1: IPS hobbies



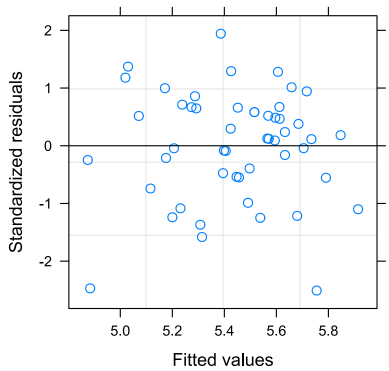
Model 1.2: IPS meal planning



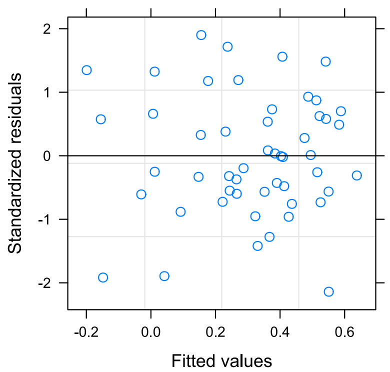
Model 2: Perceived synchrony



Model 3: Social affiliation



Model 4: Positive affect change



APPENDIX C: QUESTIONNAIRE SOCIAL AFFILIATION & SYNCHRONY

The questions regarding social affiliation and perceived synchrony were answered by the participants right after the *conversational task* and were filled out digitally on Centraxx using a slide bar (scale 1 - 7, 1 = ”not at all/ gar nicht”, 7 = ”very much/ sehr viel”). The questions were developed by Cacioppo et al. (2014) and translated to German by the author of this thesis. Here, the German version of the questions is presented to illustrate the exact wording used in this study.

Social affiliation questions

1. Wie sympathisch war Ihnen Ihr Partner? (How much rapport they felt with their partner)
2. Wie sehr haben Sie Ihrem Partner vertraut? (How much they trusted the partner)
3. Wie sehr mochten Sie Ihren Partner? (How much they liked the partner)
4. Wie gerne würden Sie mit Ihrem Partner zusammenarbeiten? (How much they would like to work with the partner)
5. Wie gerne würden Sie Ihrem Partner etwas anvertrauen? (How much they would like to confide in the partner)
6. Wie nah fühlen Sie sich Ihrem Partner? (How close they felt to their partner)

Perceived synchrony question

1. Wie synchron war die Kommunikation zwischen Ihnen und Ihrem Partner? (How synchronized was the communication between you and your partner?)

REFERENCE LIST

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AFFIDAVIT

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MMRS

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Ich erkläre hiermit an Eides statt, dass ich die vorliegende Dissertation mit dem Titel:

Produced and perceived interpersonal synchrony, social affiliation, and affect in dyadic interactions of individuals with and without Autism Spectrum Disorder

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