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THE ROLE OF IMITATION AND SYNCHRONIZATION IN EMPATHIC FUNCTIONS: INSIGHTS FROM AUTISM SPECTRUM DISORDERS

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LIST OF ORIGINAL PUBLICATIONS

This dissertation is based on the following original research articles

Study 1:

Savage, K.R., Teague, E. B., **Koehne, S**., Borod, J.C. and Dziobek, I.. A New Measure of Empathy: Psychometric Characteristics of the Cognitive and Emotional Empathy Questionnaire (in preparation).

Study 2:

Koehne, S., Schmidt, J. M., and Isabel Dziobek (2015). The role of interpersonal movement synchronization in empathic functions: Insights from Tango Argentino and Capoeira. *International Journal of Psychology*. Advance online publication. doi: 10.1002/ijop. 12213

Impact factor of this journal: 1.198

Study 3:

Dziobek, I., & **Köhne, S.** (2011). Brain imaging in autism spectrum disorders : A review. *Der Nervenarzt*, *82*(5), 564–572.

Impact factor of this journal: 0.787

Study 4:

Sowden, S.*, **Köhne, S.*,** Catmur,C., Dziobek, I., Bird; G. (2015). Intact Automatic Imitation and Typical Spatial Compatibility in Autism Spectrum Disorders: Challenging the Broken Mirror Theory. *Autism Research*. Advance online publication. doi: 10.1002/aur.1511

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Study 5:

Koehne, S., Hatri, A., Cacioppo, J.T., & Dziobek, I. (2015). Perceived interpersonal synchrony increases empathy: Insights from autism spectrum disorder. *Cognition*. Advance online publication. doi: 10.1016/j.cognition.2015.09.007

Impact factor of this journal: 3.479

Study 6:

Koehne, S., Behrends, A., Fairhurst, M., Dziobek, I. (in press). Fostering social cognition through an imitation and synchronization-based dance/movement intervention in adults with autism spectrum disorder: A controlled proof of concept study. *Psychotherapy and Psychosomatics*.

Impact factor of this journal: 9.169

SUMMARY

The early German philosopher Theodor Lipps suggested that inner mimicry of an observed movement helps us to put ourselves into the shoes of another person thereby enabling us to experience empathy with others (Lipps, 1923). He used the situation of watching a tight rope walker as an example for the experience of empathy: While watching the acrobat, the spectators participate in the movements they observe, tilting slightly to the left and right. Through mirroring the bodily experiences of the acrobat with the own body, spectators also gain a first person access to the mental states and emotions of the tightrope walker. Indeed, evidence suggests that tuning in to each other's movement through imitation and interpersonal movement synchronization serves as "social glue" (Lakin, Jefferis, Cheng, & Chartrand, 2003). Individuals with autism spectrum disorder (ASD), a developmental disorder affecting primarily communication and social interaction abilities, have difficulties understanding the minds of others and were also shown to have difficulties in imitation and synchronization. It has therefore been suggested that impairments in imitation and synchronization may add to the social deficits experienced by individuals with ASD.

The aims of this dissertation were twofold. In part I, the goal was to investigate the association of imitation and interpersonal movement synchronization with empathic functions in neurotypical individuals. Since the association between imitation and empathic functions is comparably well understood, part I focused specifically on investigating the role of interpersonal movement synchronization. A new multidimensional empathy scale was developed (Study 1; Savage et al., in preparation) for this purpose, which proved to be a valid measure of those subcomponents of empathy that are conceptually closer to embodied processes such as emotion mirroring. This measure was then used to investigate empathic functions in synchronization experts (Study 2; Köhne et al., 2015), i.e., individuals involved in physical practices that crucially rely on synchronization such as Tango Argentino. The central aim of part II of this dissertation was to characterize the association of imitation and synchronization with empathic functions in individuals with ASD. On the bedrock of a review of the neural correlates associated with ASD symptoms (Study 3; Dziobek & Köhne 2011), the link between those functions was then assessed cross-sectionally. These studies converged on the notion that imitation and synchronization are largely intact in adults with ASD but that the association to empathic functions is attenuated (Studies 4 & 5; Sowden et al., 2015, Koehne et al., 2015). Insights from all studies culminated in the evaluation of a 10-week imitation and synchronization-based dance/movement intervention, which was shown to be effective in fostering cognitive empathy skills in adults with ASD (Study 6: Koehne et al., in press).

ZUSAMMENFASSUNG

Bereits der Philosoph Theodor Lipps vermutete dass ein Prozess der inneren Nachahmung von beobachteten Bewegungen uns hilft, uns in andere einzufühlen (Lipps, 1923). Als Beispiel beschrieb er die Beobachtung eines Seiltänzers: Während die Zuschauer dem Akrobaten zusehen, beugen sie sich mit ihm leicht nach rechts und links. Indem sie die körperlichen Erfahrungen des Akrobaten mit dem eigenen Körper spiegeln, können sie sich in den Beobachteten hineinversetzen und so seine mentalen und emotionalen Zustände mitempfinden. Tatsächlich gibt es Belege dafür, dass synchrone Bewegungen und das Imitieren von Bewegungen wie ein "sozialer Klebstoff" wirken (Lakin, Jefferis, Cheng, & Chartrand, 2003). Menschen mit Autismus Spektrum Störungen, einer tiefgreifenden Entwicklungsstörung, die vor allem Kommunikations- und soziale Interaktionsfähigkeiten beeinträchtigt, haben Schwierigkeiten, die Gedanken und Gefühle anderer zu verstehen. Zudem weisen Befunde darauf hin, dass sie Schwierigkeiten in der Imitation und Synchronisation von Bewegungen haben. Daher wurde vermutet, dass Defizite in Imitation und Synchronisation zu ihren sozialen Defiziten beitragen.

Diese Dissertation verfolgt zwei Ziele: In Teil I wird der Zusammenhang von Imitation und interpersoneller Synchronisation mit Empathiefunktionen in neurotypischen Menschen untersucht. Da der Zusammenhang zwischen Imitation und Empathiefunktionen bereits vergleichsweise gut untersucht wurde, liegt der Fokus hier insbesondere auf der Rolle zwischenmenschlicher Synchronisation von Bewegungen. Hierzu wurde zunächst eine neue mehrdimensionale Empathieskala entwickelt und gezeigt, dass diese ein valides Maß für solche Subkomponenten der Empathie darstellt, die konzeptuell mehr auf körperlichen Prozessen basieren. Diese Skala wurde dann verwendet, um Empathiefunktionen in Experten der zwischenmenschlichen Synchronisation zu untersuchen, d.h. Menschen, die Tänze praktizieren, welche besonders die zwischenmenschliche Synchronisation von Bewegungen erfordern, wie z.B. Tango Argentino. Teil II dieser Dissertation untersucht den Zusammenhang von Imitation und Synchronisation mit Empathiefunktionen in Menschen im Autismus Spektrum. Auf Grundlage einer Übersicht über neuronale Korrelate autistischer Symptome, wurden diese Zusammenhänge zunächst querschnittlich untersucht. Zusammengenommen zeigten diese Studien, dass Imitation und Synchronisation als solche weitgehend intakt sind bei Menschen im Autismus Spektrum, der Zusammenhang zu Empathiefunktionen jedoch geschwächt ist. Dier Erkenntnisse aller Studien mündeten dann in der Evaluation einer 10-wöchigen imitations- und sychronisationsbasierten Tanz- und Bewegungsintervention, die erfolgreich kognitive Empathie bei Erwachsenen im Autismus-Spektrum fördern konnte.

1 INTRODUCTION

1.1 AUTISM SPECTRUM DISORDER

1.1.1 CLINICAL CHARACTERISTICS

Autism spectrum disorder (ASD) refers to an etiologically and clinically heterogeneous group of disorders, characterized by pervasive qualitative impairments in social interaction and communication, such as eye contact, intonation and facial expression, and restricted stereotyped patterns of behaviors and interests, ranging from finger manerisms to preoccupation with heating vents. Although ASD are defined by these shared difficulties, individual symptoms vary widely. Deficits in developing, maintaining, and understanding relationships for example, may present as an absence of interest in peers or as difficulty in making friends (American Psychiatric Association, 2013). While children may have difficulties in sharing imaginative play, adults often experience more subtle deficits such as adjusting behavior to suit various social contexts (American Psychiatric Association, 2013). Restricted behavior may present as insistence on sameness, inflexible adherence to routines, or ritualized patterns or verbal nonverbal behavior (e.g., extreme distress at small changes, difficulties with transitions, rigid thinking patterns, greeting rituals, need to take same route or eat food every day) (American Psychiatric Association, 2013).

Based on American psychiatrist Leo Kanner's descriptions of "autistic disturbances of affective contact"(Kanner, 1943) and "early infantil autism" (Kanner, 1944), autism was first officially recognized as a diagnosis in 1980 by its inclusion into the internationally used Diagnostic and Statistical Manual of Mental Disorders, 3rd edition (DSM-III, American Psychiatric Association, 1980). Almost simultaneously to Kanner's reports, Hans Asperger in Austria used the term "autistic psychopathy" for a group of cases in which boys had severe social impairment and motor problems but apparently good verbal skills (Asperger, 1944). Based on his reports and following research, the Asperger's Syndrome was introduced as a condition distinct from autism fourteen years later (DSM-IV, American Psychiatric Association, 1994).

Until recently, both internationally used diagnostic classification systems, the ICD - 10 and the DSM - IV listed autism and Asperger's Syndrome in the category of pervasive developmental disorders (PDD), together with pervasive developmental disorder - not otherwise specified (PDD - NOS), Rett's syndrome, and childhood disintegrative disorder (American Psychiatric Association, 2000; World Health Organization, 1993). All PDD describe neurodevelopmental conditions characterized by the symptom trias of pervasive qualitative impairments in social interaction and communication, and restricted stereotyped patterns of behaviors and interests, but differ in their developmental course and symptom constellations. For instance, in contrast to Asperger's Syndrome, a diagnoses of autism requires an impaired or significantly delayed language development, while PDD-NOS is a subthreshold condition for cases with problems suggestive of autism but failure to meet full diagnostic criteria (American Psychiatric Association, 2000).

Although not an official term under DSM-IV, clinicians and researchers have used "autism spectrum disorders" as an umbrella term to include autism, Asperger's syndrome, and PDD-NOS (Levy, Mandell, & Schultz, 2009), reflecting a common opinion that these conditions should be regarded as part of a autism continuum rather than valid subtypes of PDD (Baron-Cohen & Hammer, 1995; Mayes, Calhoun, & Crites, 2001). In line with this, the PDD class was merged into a single class of ASD in the fifth edition of the DSM (DSM-V, American Psychiatric Association, 2013), and a related disorder, social communication disorder, was added. The umbrella category of ASD encompasses the previously distinct PDDs of autistic disorder, Asperger's disorder, and PDD-NOS. The triad of impairments was collapsed into two domains, preserving restricted and repetitive behaviors but merging social and communicative difficulties into a single domain. The new diagnostic category, social communication disorder, defined by pragmatic difficulties and problems in the use of verbal and nonverbal communication in social contexts, was introduced as a distinct disorder from ASD; although similar to PDD-NOS in many regards, it is grouped as a communication disorder and with a corresponding ICD-10 code mapping onto specific developmental disorders of speech and language. DSM-V criteria for ASD introduce a series of specifiers, reflecting a volume-wide effort to include themes and descriptors that apply transdiagnostically. These addenda provide related information about the current presentation of a person meeting criteria for ASD, such as symptom severity, intellectual and language impairment. While some studies suggested that more than 50% of individuals with a DSM-IV diagnosis of ASD would not meet revised diagnostic criteria (for an overview, cf. Volkmar & McPartland, 2014), a study with a large sample size evaluated with standardized instruments demonstrated approximately 91% sensitivity, suggesting that individuals previously meeting criteria for ASD will continue to do so according to the DSM-5 (Huerta, Bishop, Duncan, Hus, & Lord, 2012).

Individuals with ASD who participated in the studies of this dissertation were diagnosed with either autism without intellectual impairment or Asperger's Syndrome according to DSM-IV criteria. The term autism spectrum disorder will be used throughout the following sections to refer to this specific population.

1.1.2 EPIDEMIOLOGY AND BURDEN OF AUTISM SPECTRUM DISORDERS

In the past decade, rising prevalence rates of ASD strengthened public fears that an ‘epidemic’ of ASD was afoot (Weintraub, 2011). While the estimates were around 1 in 50.000 in 1975 they increased to up to 1 in 110 in 2009 (Weintraub, 2011). A provocative study published in The American Journal of Psychiatry in 2011 presented evidence for even higher rates of ASD (3.74% in males and 1.47% in females) in school-age children in a South-Korean community (Kim et al., 2011). There is evidence that the broadening of the concept and the expansion of diagnostic criteria (cf. section 1.1.1), together with the development of services, and improved awareness of the condition, have played a major role in explaining this increase, although it cannot be ruled out that other factors might have also contributed to that trend (Fombonne, 2009; Weintraub, 2011).

A recent, methodologically particularly thorough study captured prevalence data from a range of sources using both, registry data and comprehensive case-finding strategies, and using covariates to adjust for sources of systematic bias (Baxter et al., 2014). After adjusting for variable study methodology, it was shown that the prevalence of ASD seems to have remained relatively stable over the past 20 years at 7.6 in 1000 or 1 in 132. Notably, this rate is comparable to other major psychiatric disorders such as schizophrenia, the life time prevalence of which was shown to lie around 4.0 in 1000 (Saha, Chant, Welham, & McGrath, 2005).

This study was also the first to calculate the burden of ASD. The Global Burden of Disease initiative conceptualizes burden as health loss due to morbidity (years lived with disabilities, YLDs) and mortality (years of life lost, YLLs), which are then summed to derive overall burden in terms of disbility-adujusted life-years (DALYs). According to (Baxter et al., 2014), global burden of ASD arose to 7.7 million DALYs across the globe. In comparison to other mental disorders that commence in childhood, the total burden of ASD was greater than that of conduct disorder and ADHD combined (DALYs = 6.2 million). Unlike disorders such as ADHD, which demonstrates substantial remission from adolescence onwards, there is limited clinical or epidemiological evidence of remission in ASD (Baxter et al., 2014). This results in burden that commences in infancy and persists across the lifespan.

Taken together, these studies make clear that ASD rates are higher than previously expected and as high as other major psychiatric disorders such as, e.g., schizophrenia, and lead to a significant burden, thus pointing to the importance of understanding and treating this disorder better.

1.1.3 ETIOLOGY OF ASD

Since the seminal twin studies by (Folstein & Rutter, 1977), comparing concordance rates for autism in monozygotic twins and dizygotic twins, it is widely accepted that ASD is a predominantly genetically determined disorder with an estimated heritability of around 90% (Freitag, 2007). Despite the high-heritability estimates for ASD, no major gene has been observed to be relevant for the majority of ASD diagnoses. Although syndromes that are known to be caused by single-gene mutations, such as Joubert Syndrome, Smith–Lemli–Opitz syndrome, Tuberous Sclerosis and Fragile X, are associated to increased ASD rates, ASD is not observed in all affected individuals (fragile-X-syndrome ca. 25% (males), tuberous sclerosis ca. 20%; Smith–Lemli–Opitz ca. 50%), thus excluding the respective genes as a major cause of ASD (Freitag, Kleser, Schneider, & von Gontard, 2007). Over all, none of these rare syndromes accounts for more than 1% of all ASD (Abrahams & Geschwind, 2008). Instead, idiopathic autism (i.e. those with no obvious clinical syndrome) was thought to be explicable by the so-called complex genetic model suggesting that multiple common variants interact with each other and with environmental factors to lead to autism (Geschwind, 2011). In contrast to Mendelian genetics, the complex genetic model assumes that specific common variants in genes increase susceptibility to ASD but each is not on its own sufficient to be causal. These same variants are thought to contribute to normal variation in cognition and behavior in unaffected individuals thus explaining the presence of subthreshold traits in non-autistic first-degree relatives. However, whole genome association studies with common variants, although identifying a few loci with very small effect sizes, have not yielded independently replicated results (Freitag et al., 2007).

Owing to technical advances, recent studies have focused on copy number variations (CNV), defined as rare mutations in the form of submicroscopic chromosomal structural variation within a longer DNA segment (longer than 1 kb), such as deletion, insertion, duplication, that could not be detected with more traditional methods (Freitag, Staal, Klauck, Duketis, & Waltes, 2010). CNVs can be inherited or may arise de novo on a paternally or maternally inherited chromosome. Although some CNVs are observed more frequently in ASD patients compared to control subjects, some of these CNV were observed also more frequently in individuals with mental retardation or schizophrenia than in controls, thus lacking specificity for ASD in particular. Taken together, in contrast to the complete absence of any biological understanding of the ASD as recently as 30 years ago, we now know that defined mutations, genetic syndromes and de novo CNV account for about 10–20% of ASD cases (Abrahams & Geschwind, 2008).

Although the main research attention has focused on genetic influences, evidence suggests that most ASD constitute multifactorial disorders. That means that some kinds of non-genetic factors are also likely to play a part in the etiology of ASD. Some research has found that social changes leading to having children at an older age explains 10% of the increase of ASD prevalence rates (higher risk for parents older than 35) (Weintraub, 2011). Prenatally, toxins and certain conditions of the mother have been associated with ASD, such as hypothyroidism, thalidomide use, valproic acid use, cocaine or alcohol use, and congenital cytomegalovirus and rubella infections, while it is unlikely that they constitute commonly operating risk factors for ASD (Rutter, 2005). Obstetric complications most likely do not constitute an environmentally mediated risk but rather reflect a response to a genetically abnormal fetus (Rutter, 2005). Findings that ASD is more common in high socio-economic classes, and among children born to immigrant parents are contradictory, inconclusive and based on small numbers (Rutter, 2005). Another line of research suggested a link to the measles, mumps and rubella vaccination, causing a significant impact on immunisation uptake and herd immunity, is now robustly refuted by wide- ranging research (Simonoff, 2012).

Taken together, although much research has been conducted in the past decades focusing on genetic causes of ASD, the causes of ASD remain still widely unknown. As a result, research is needed that focuses on understanding the more basic mechanisms underlying the more complex social deficits, in order to pave the way for potential treatment approaches.

1.2 EMPATHY

Empathy is a broad term that has played an important role in various fields from the philosophy of aesthetics to neuroscience, and thus has been defined from various stances. The next chapter defines empathy as used in this dissertation based on the origin of the term and latest research results.

1.2.1 THE ORIGIN OF THE TERM EMPATHY

In everyday use, the term empathy refers to understanding and sharing the mental states of other persons (de Vignemont & Singer, 2006). It has its origins in the Greek word ‘empatheia’ (passion), which is composed of ‘en’ (in) and ‘pathos’ (feeling). The term empathy was introduced into the English language following the German notion of *Einfühlung* (feeling into), which originally described resonance with works of art and only later was used to describe the resonance between human beings. The early German philosopher Theodor Lipps used the experience of watching a tight rope walker as an example for the experience of *Einfühlung*: While watching the acrobat, the spectators participate in the movements they observe, tilting slightly to the left or right, and holding their breath as if it were them balancing high above the arena. Through mirroring the bodily experiences of the acrobat with the own body, spectators also gain a first person access to the mental states and emotions of the tightrope walker. Based on Lipps' concept of movement simulation, dance critic (Martin, 1936) proposed that an audience experiences the emotions communicated by modern dance through inner mimicry, i.e., by directly experiencing the observed movements and their associated movements.

In spite of the philosophical interest for empathy it was not until the late 20th century that researchers from social and developmental psychology started to study this phenomenon scientifically. Subsequent work converged on the notion that the term empathy subsumes a variety of dissociable processes that can be broadly divided into cognitive aspects of empathy (e.g., understanding thoughts, emotions and intentions of another person) and emotional aspects of empathy (e.g., feeling with another person). Interestingly, embodied interpersonal processes, such as motor simulation, which closely match Lipps' original concept of *Einfühlung* gained much less attention and have only recently been investigated more systematically under the label of motor or kinesthetic empathy (Blair, 2005; Bons et al., 2013; Foster, 2011; Keysers, Meffert, & Gazzola, 2014; Shamay-Tsoory, 2011). This dissertation attempts to follow empathy to its roots and shed light on this third component that has been suggested to play an important role in psychiatric disorders such as autism (Blair, 2005) and to elucidate its relation to cognitive and emotional empathy (Figure 1). The following sections define all three components - cognitive, emotional and kinesthetic– for this dissertation and introduce common operationalizations.

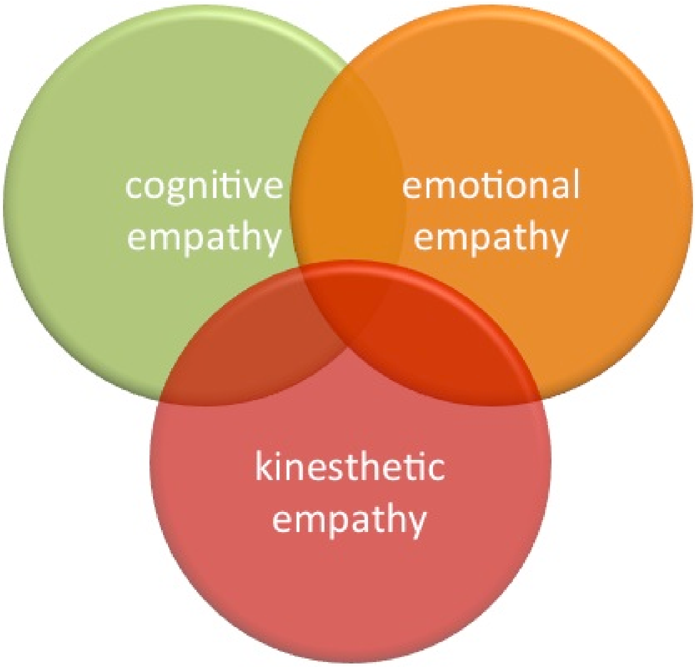

Figure 1. Subcomponents of empathy

1.2.2 EMOTIONAL EMPATHY

Broadly defined, emotional aspects of empathy comprise all vicarious emotional responses to the perceived emotional experiences of others (Mehrabian & Epstein, 1972), including phenomena such as emotional contagion, empathic concern, and personal distress. In a more narrow definition, emotional empathy is conceptualized more narrowly as emotion mirroring, i.e. sharing the feelings of another person (Preston & de Waal, 2002). Thus in addition to an affective response to another person's emotional state, this definition requires the response to be isomorphic to the other person's affective state. Consequently emotionally incongruent phenomena are excluded, such as, e.g., empathic concern, which refers to feeling *for* rather than *with* someone, e.g., positive feelings of warmth and compassion for somebody in distress. Some researchers follow this road down even further by narrowing the entire term of empathy down to this emotion sharing process, thus excluding all purely cognitive aspects (de Vignemont & Singer, 2006). Constraining emotional empathy and general empathy, respectively, to affect sharing was motivated at least partly by social neuroscience, investigating the neural basis of empathy. Functional magnetic resonance imaging (fMRI) studies have shown that observing another person's emotional state activates parts of the neuronal network involved in processing that same state in oneself, whether it is disgust (Wicker et al., 2003), touch (Keysers et al., 2004) or pain (Singer et al., 2004). These findings suggest that emotion mirroring has a distinct neural correlate that can be dissociated from other emotional responses to the perceived emotional experiences of others. This dissertation opts for the broad definition of emotional empathy to indicate the relatedness of all further subcomponents. It is suggested that subcomponents such as emotion mirroring should be named by those more descriptive terms in order to enhance transferability of results across studies and disciplines. Therefore, emotional empathy is used as an umbrella term and more specific terms are used when referring to specific subcomponents. Due to its conceptual closeness to imitation and synchronization, emotion mirroring played a particularly important role in this dissertation.

As for all emotional processes, the subjectivity of emotional empathy makes it notoriously hard to operationalize. Consequently, attempts to measure emotional empathy often rely on self-report measures. It is therefore all the more surprising, that despite the growing interest in the study of empathy, there is a lack of a timely measures of emotional empathy that take into account findings from current neuroscientific research. The Interpersonal Reactivity Index (IRI) (Davis, 1983), which was developed more than 30 years ago, still is one of the most commonly used empathy questionnaires, that is also frequently applied in social neuroscience (Decety, 2011). However, oblivious of neural basis of empathy, the IRI omits emotion mirroring altogether while focusing instead on empathic concern and personal distress. Other commonly used questionnaires such as the Empathy Quotient (Baron-Cohen & Wheelwright, 2004) don't differentiate between different aspects of empathy and even include items for cognitive empathy. It was therefore a specific aim of this dissertation to develop a timely self-rating measure of empathy based on recent evidence.

The Multifaceted Empathy Test (MET) (Dziobek et al., 2008) captures emotion mirroring by using pictures showing people in emotional situations and asking probands to indicate on a Likert scale how much they feel with that person. This measure is not only conceptually closer to emotion mirroring, but also more naturalistic than paper and pencil measures. In addition, it covers positive in addition to negative emotional states, such as feeling happy when seeing someone who experiences joy, thus providing a means to capture mirroring of full emotion spectrum. It was therefore used in this dissertation in addition to self-report measures to capture emotional empathy.

Attempts to capture emotional empathy more objectively involve measuring physiological reactions, such as heart rate and skin conductance, to emotional facial expressions (Bons et al., 2013). For example, De Wied et al. (2009) measured heart rate reactivity to documentary scenes with people experiencing sadness to assess emotional empathy in boys with disruptive behavior disorders. Although this method represents an objective way of operationalizing emotional empathy, most physiological measures do not respond differentially to experiencing positive and negative emotions, let alone more complex emotions such as shame or greed, thereby preventing to assess in how far the emotional reaction is congruent to the perceived affective state (Bons et al., 2013). For instance, changes in skin conductance while seeing an angry person may result from arousal through fear rather than shared anger.

Therefore, in this dissertation, the attempt is made to develop a new self-rating measure of empathy that includes emotion mirroring. This newly developed scale is complemented with more established methods, such as the IRI to measure other emotional aspects associated with empathy and the MET to operationalize emotional empathy.

1.2.3 COGNITIVE EMPATHY

Cognitive empathy refers to the ability to understand what other people are thinking and feeling, and is thus an umbrella term for processes such as emotion recognition, mental state inference, and perspective taking, all of which require Theory of Mind (ToM), i.e. the ability to represent another person's psychological perspective (Amodio & Frith, 2006). For instance, in the "Reading the Mind in the Eyes Test" (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001), the participant is presented with a series of photographs of the eye-region of the face of different actors and actresses, and is asked to choose which of four words best describes what the person in the photograph is thinking or feeling (e.g., interested, hostile). This test was conceived of as a test of how well the participants can put themselves into the mind of the other person, and ''tune in'' to their mental state (Baron-Cohen et al., 2001). In another test designed to measure mental state inference, subjects view animations of geometric shapes that move and interact in a way that elicits attributions of mental states (e.g., the big triangle is "chasing" the small triangle). The narratives that subjects provide to describe these scenes are then coded in terms of their abilities to attribute social meaning to the geometric shapes (Heider & Simmel, 1944; Klin, 2000). Both tests have been used in various studies since they were first introduced, including neuroscientific studies (Baron-Cohen & Hammer, 1995; Castelli, Frith, Happé, & Frith, 2002; Domes, Heinrichs, Michel, Berger, & Herpertz, 2007). The artificiality of the stimuli used in these tests (photographs of the eye-region and cartoons of geometric shapes) shows how researchers struggle to design a test which is sensitive to subtle cognitive dysfunction in adults and try to do so by reducing the social information provided by the stimuli. The "Movie for the Assessment of Social Cognition" (MASC) (Dziobek et al., 2006) reconciles ecological validity and task sensitivity. In this task, participants watch a short film showing four persons spending an evening together with the instruction to try to understand the mental states of the characters and to answer 45 multiple choice questions at given breaks (e.g., "What is Cliff thinking?", "Why is Michael doing this?"). Although the film scenes are rich in social information, the MASC was shown to be sensitive to subtle deficits in mind reading in adults (Dziobek et al., 2006; Montag et al., 2011; Preißler, Dziobek, Ritter, Heekeren, & Roepke, 2010; Ritter et al., 2011). It is therefore a prominent measure of cognitive empathy in this dissertation.

The more general ability to represent another person's psychological perspective (ToM) is commonly tested using stories in which the mental state of the protagonist differs from that of the reader (so-called false belief stories). For instance, in the classic Sally and Anne task, a comic strip depicts Sally placing her marble in a basket and then goes out to play (Baron-Cohen, Leslie, & Frith, 1985). In her absence, a second character, Anne, moves the marble from the basket to a box with the result that Sally has a false belief about the marble's location. When Sally returns, subjects are asked test questions that require them to infer Sally's false belief such as where Sally thinks the marble is.

Importantly, false belief tasks require the ability to overcome an egocentric perspective in order to infer another person's incongruent perspective, an ability that has been said to require self-other distinction rather than tuning in to another person (Keysar, Barr, Balin, & Brauner, 2000; Santiesteban, Banissy, Catmur, & Bird, 2012.

Taken together, cognitive empathy is a rather general term for “mind reading” abilities that have been measured using a variety of tasks of different ecological validity, and involve tuning in to someone as in the Reading the Mind in the Eyes task as well as in some cases overcoming an egocentric psychological perspective as in the false belief task.

1.3 KINESTHETIC EMPATHY

1.3.1 THE EMBODIMENT OF EMPATHY

Following suit of the early definitions from aesthetic philosophy, which defined empathy as an inherently embodied process of feeling into others (Lipps, 1923), scholars from dance studies and dance history coined the term “kinesthetic empathy” to describe the process through which spectators of dance gain an aesthetic reception of a dance piece (Martin, 1936; Sklar, 1994). The term kinesthesia, although having undergone several revisions since its coining in 1880 (Foster, 2011), can broadly be defined as the sensation of movement and body posture, integrating proprioceptive and other sensory information from inside and outside the perceiving organism (Proske, 2006). Dance researchers interested in the aesthetic reception of modern dance used the term kinesthetic empathy to refer to spectators’ muscular and emotional responses to watching dancers, arguing that inner mimicry of dance movement involved associated changes in physiological states and emotion (Foster, 2011; Martin, 1936; Reason & Reynolds, 2010). They proposed that modern dance was primarily interested in communicating emotional experiences through movement, and that inner mimicry would give spectators the sense that they were actively participating in the dance and directly experiencing both its movements and their associated emotions. Kinesthetic empathy became thus a paradigm of response that could enable spectators to make sense of modern dance, which had deprived spectators of familiar landmarks in terms of narrative and classical ballet vocabulary (Foster, 2011; Martin, 1936; Reason & Reynolds, 2010). Interestingly, an interdisciplinary effort was made more recently to investigate the role of kinesthetic empathy in audience experience of dance using methods from experimental psychology (www.watchingdance.org). Indeed, it could be shown that frequent ballet spectators showed larger motor-evoked potentials in the arm muscles when watching ballet compared to when they watched other performances, confirming that spectators covertly simulate the movements for which they have acquired visual experience (Jola, Abedian-Amiri, Kuppuswamy, Pollick, & Grosbras, 2012).

In line with this approach, the current dissertation argues that in the context of social interaction, kinesthesia is an important aspect of empathy because it refers to a person’s own corporal feeling as a response to the body movements or posture of others. Thus, the kinesthetic dimension of empathy allows us to feel the physical state of another person with our own body (Behrends, Müller, & Dziobek, 2012). The relevance of the kinesthetic aspect of empathy is highlighted in the context of embodiment theory. Leaving the cognitive turn of the 1970s behind, this new wave in psychology seeks to ascertain the body motor system's contribution to psychological processes (Glenberg, 2010; Marsh, Richardson, & Schmidt, 2009; Tschacher, 2010). Importantly, adopting an embodied perspective opens doors for interdisciplinary collaborations, which also play a crucial role in this dissertation.

Experimental psychological research has started to shed light on embodied interpersonal processes that closely match Lipps' original concept of motor simulation referring to related processes as "motor empathy" (Blair, 2005; Hatfield, Cacioppo, & Rapson, 1993). It was shown that coordinated joint action, such as falling into lock-step when walking side-by-side, often emerges spontaneously during human interaction and enhance social processes (Marsh et al., 2009). Two ways in which individuals coordinate their movements are through imitation and interpersonal movement synchronization both of which have been shown to enhance, e.g., affiliation, emotional connection, feeling understood, and emotion recognition (for a review, cf. Chartrand & Lakin, 2013). In the following, previous findings on how 1) imitation and 2) interpersonal movement synchronization relate to social processes are summarized.

1.3.2 Imitation as a Precursor of Empathy

It has repeatedly been shown that imitation of, e.g., gestures and facial expressions entails positive social consequences including liking, emotion recognition, generosity, and reduced racial prejudice (Dimberg, Thunberg, & Elmehed, 2000; Inzlicht, Gutsell, & Legault, 2012; Stel & van Knippenberg, 2008; van Baaren, Holland, Steenaert, & van Knippenberg, 2003). The fact that imitation is an inherently social process is further underlined by findings showing that the tendency to imitate others is modulated by various social factors. For instance participants are more likely to mimic behavior of a confederate (such as pen playing), when he is presented as likable, as a member of the in-group or simply after participants were primed with pro social words (Chartrand & Lakin, 2013). Although people intentionally imitate each other all the time, and this is an important component of social learning (Bandura, 1977), imitation is often non-conscious, unintentional, and effortless (Chartrand, Maddux, & Lakin, 2005). It has been shown for example that during conversations participants spontaneously engage in more foot shaking when with a foot-shaking than face-touching confederate, and more face touching when with a face-touching than foot-shaking confederate (Chartrand & Bargh, 1999). In another study, participants exposed to emotional facial expressions (happy and angry) reacted with distinct facial muscle reactions as measured through facial electromyography, although a backward-masking technique prevented them from consciously perceiving the pictures

(Dimberg et al., 2000).

Today, a vast amount of literature shows that the mere observation of a human action activates a corresponding motor representation in the observer, suggesting that perception and action rely on a ‘shared representational system’ (Prinz, 1997). The neural correlate for perception–action coupling has been named the mirror neuron system and is localized in the inferior frontal gyrus and parietal areas (inferior parietal lobule and superior temporal sulcus) (Van Overwalle & Baetens, 2009). It has been hypothesized that the pro social consequences of imitation rely on an activation of the mirror neuron system blurring the boundaries between the self and the other by simulating the other’s bodily state. During observation of the bodily state of someone else, the same mirror neuron structures are activated in the observer as in the person observed, so that an internal simulation is generated enabling implicit understanding of the other's mind (Gallese, 2008, 2009).

A more recent line of research showed an association of top down modulation of automatic imitation (imitation *inhibition*) and social cognitive functions that require to differentiate between self and other, such as perspective taking (Brass, Ruby, & Spengler, 2009; Santiesteban, Banissy, Catmur, & Bird, 2012; Santiesteban, White, et al., 2012). The authors suggest that both processes, imitation inhibition and perspective taking, rely on a neural network, which modulates the mirror neuron system and supports the top-down control of representations of ‘self’ and ‘other’, namely the medial prefrontal cortex and the temporo parietal junction. These authors imply that simulating the mental state of another person through mirroring leads to an egocentric bias and thus disrupts cognitive empathy (Brass et al., 2009; Spengler, von Cramon, & Brass, 2009). The rational behind this is that during simulation the subject projects her own view onto others and thus, modulation of the mirror neuron system is required for self-other differentiation to ascribe a representation held in the mirror neuron system to either the self or the other (Spengler et al., 2009). Indeed, it was shown that training imitation *inhibition* and thus top down control of simulation enhanced perspective taking abilities and stimulation of the temporo parietal junction through transcranial direct current stimulation increased both functions, imitation inhibition and perspective taking (Santiesteban, Banissy, et al., 2012; Santiesteban, White, et al., 2012).

Taken together, a vast amount of literature both from behavioral and neuroscientific studies, supports an association of imitative and empathic functions, although the exact mechanism of this association remains controversial.

1.3.3 Synchronization as a Precursor of Empathy

Interpersonal movement synchronization is another way through which individuals coordinate their behavior, the social consequences of which are less well understood than those of imitation. It has been shown that like imitation, synchronization leads to pro social consequences: synchronizing movements with those of another person during an interaction is associated with greater rapport, feelings of closeness and pro-social behavior (Bernieri, 1988; Cacioppo et al., 2014; Catmur & Heyes, 2013; Hove & Risen, 2009; Kirschner & Tomasello, 2010; Wiltermuth & Heath, 2009). Moderators of interactional synchrony effects are remarkably similar to the moderators of imitation; people synchronize more with others with whom they have positive relationships (Miles, Griffiths, Richardson, & Macrae, 2010), those with whom they might want to develop positive relationships (Miles, Lumsden, Richardson, & Neil Macrae, 2011) and those with whom they have self-disclosed (Vacharkulksemsuk & Fredrickson, 2012). Additionally, people who either dispositional or temporarily have a pro social orientation synchronize their behaviors with interaction partners more than people who have a pro self orientation (Lumsden, Miles, Richardson, Smith, & Macrae, 2012). Like with imitation, synchronization with behavior of other human individuals often occurs unintentionally (Issartel, Marin, & Cadopi, 2007; Lorenz, Mörtl, & Hirche, 2013; Richardson, Marsh, Isenhower, Goodman, & Schmidt, 2007; van Ulzen, Lamoth, Daffertshofer, Semin, & Beek, 2008). While imitation and interpersonal synchronization share certain features, they also differ in important ways. As a result they are considered as two different processes. Whereas imitation always yields behaviors that are similar in form and close in timing, synchronization may or may not yield behaviors that are similar in form. Although behaviors are temporarily close in imitation, timing of behavior is critical to determining whether one person behaves synchronously with others (Chartrand & Lakin, 2013).

To conclude, although evidence suggests that interpersonal synchronization entails similar pro social consequences as imitation, much less is known about this aspect of interpersonal movement coordination. This dissertation therefore aims specifically at elucidating the association of synchronization and empathic functions.

1.4 Empathic Functions in Autism Spectrum Disorder

Impairments in empathy have been regarded as a central characteristic of ASD (Baron-Cohen & Wheelwright, 2004). Indeed, it has consistently been shown that individuals with autism have difficulties in cognitive empathy. Research suggests that impairments in cognitive empathy in autism can be detected as early as around 18 months (Charman & Swettenham, 1997). At this age, typically developing infants show more joint attention and pretend play than children with autism, which likely requires the ability to model other peoples' minds. In everyday-life, the mindreading difficulties of individuals with ASD are seen in the inability to tell lies, keep secrets, or understand that others can hold false beliefs (for a review, cf. Frith, 2004). A large number of studies have repeatedly demonstrated that individuals with autism have difficulties in shifting their perspective to judge what someone else might think, instead simply reporting what they themselves know (for reviews cf. Baron-Cohen et al., 1985; Baron-Cohen, 2001). In addition, individuals on the autism spectrum have been shown to have problems processing facial expressions of basic emotions and of more complex mental states (Harms, Martin, & Wallace, 2010; Kleinman, Marciano, & Ault, 2001).

In contrast, findings on emotional empathy are more inconsistent. While most studies that used self-rating measures report lower emotional empathy in individuals with ASD than neurotypical participants, emotional empathy is often reported as intact in studies using more objective measures (Rueda, Fernández-Berrocal, & Schonert-Reichl, 2014). In the empathy for pain paradigm for example the physical or neural response to pictures of others receiving painful stimuli such as a cut with the knife in the finger serves as a proxy for emotional empathy and has been found to be statistically inseparable from the reaction of neurotypicals (Bird et al., 2010; Hadjikhani et al., 2014). When measured simultaneously, the pattern of impaired cognitive but spared emotional empathy was found (Dziobek et al., 2008). Although more research is needed to fully understand emotional empathy in individuals with ASD, these results hint at a heterogeneous empathy profile, which highlights the importance of a more fine-grained investigation of empathic functions.

1.5 Imitation and Synchronization in Autism Spectrum Disorder

Due to the theorized importance of imitation for the development of sociocognitive abilities including cognitive and emotional empathy (Rogers & Pennington, 1991), researchers in search of an explanation for the social deficits have focused on the ability of individuals with ASD to imitate. The focus on imitation in ASD has been further increased due to the claim that an atypical or ‘broken’ mirror neuron system, the neural system subserving imitation (Catmur, Walsh, & Heyes, 2009; Heiser, Iacoboni, Maeda, Marcus, & Mazziotta, 2003), may be responsible for the symptoms of ASD (Ramachandran & Oberman, 2006). The Broken Mirror Theory has prompted a great deal of research examining the structural and functional integrity of the mirror neuron system in autism (for a review, cf. Hamilton, 2013). However, empirical evidence examining the Broken Mirror Theory has produced mixed results, with as many studies reporting typical mirror neuron structure and function in ASD as those finding impairments (Hamilton, 2013).

The first systematic review of imitative behavior in ASD concluded that there is evidence of a specific imitation impairment in autism (Williams, Whiten, Suddendorf, & Perrett, 2001). However, all of the reviewed studies measured intentional or voluntary imitation, where the participant is explicitly asked to copy a model action. These typically involve a number of higher-level cognitive processes known to be impaired in individuals with ASD however, such as executive function, pragmatic language understanding, and rapid attentional switching (Courchesne et al., 1994; Mitchell, Russell, & Saltmarsh, 1997; D. L. Williams, Goldstein, Carpenter, & Minshew, 2005). Thus, it may be impairments in processes other than imitation, which lead to poor performance in tasks of voluntary imitation (Bird, Leighton, Press, & Heyes, 2007). Thus, despite a vast amount of research it is not clear whether there is a specific imitation deficit in individuals with ASD and what role it plays for the impaired social cognitive functions.

In addition to imitation deficits, less spontaneous synchronization and difficulties voluntarily synchronizing with another person have recently been reported for individuals with ASD and have been suggested to also contribute to their social deficits (Fitzpatrick, Diorio, Richardson, & Schmidt, 2013; Gowen & Miall, 2005; Marsh et al., 2013). For instance, Marsh et al. (2013) showed that children with ASD tend to synchronize their rocking-chair movements less to those of their parents compared to typically developing children. However, associations of synchronization with social impairments have not been invested directly in individuals with ASD.

This dissertation therefore aims at systematically investigating whether there is general deficit in imitation and synchronization and how these functions relate to empathy in individuals with ASD.

1.6 FOSTERING EMPATHY IN INDIVIDUALS WITH AUTISM SPECTRUM DISORDER

1.6.1 CHILDREN

Several attempts have been made to foster social functioning in general and empathic functions specifically in children with ASD (for a review, cf. Fletcher-Watson, McConnell, Manola, & McConachie, 2014; Rao, Beidel, & Murray, 2008). Those social functioning interventions can be contrasted with other types of treatment for ASD. Many intervention models focus on behavior management and personal skills training, using a basic conditioning model for learning (repetition; rewarding desirable behavior; 'punishing' or ignoring unhelpful behavior) (see Horner, Carr, Strain, Todd, & Reed, 2002 for a review). Interventions designed to foster empathic functions focused in particular on enhancing cognitive functions, such as emotion recognition and mind reading (e.g., Baghdadli et al., 2013; Ryan & Charragáin, 2010; B. T. Williams, Gray, & Tonge, 2012), and have used a wide range of approaches from group settings to DVD-based teaching. Studies consistently found positive effects, when emotion recognition and mind reading were tested under the same circumstances, using the same material or interaction partner (Fletcher-Watson et al., 2014). However, generalization to testing contexts that moved beyond the trained content was a greater challenge (Fletcher-Watson et al., 2014). Of note, one intervention study with toddlers targeted imitation abilities directly to foster social functions (Ingersoll, 2012). Although results were limited by small effect and sample sizes (N = 27), the positive results on imitation and social functions point to the value of trying to use an embodied approach to fostering empathic functions in adults with ASD.

1.6.2 ADULTS

Deficits in social cognition persist into adulthood and impair the social and professional lives of individuals with ASD (Levy & Perry, 2011). Beyond this, adults with ASD suffer from comorbid psychiatric conditions, such as depressive and anxiety disorders, at higher rates than both the general population and individuals with other developmental disabilities, which indicates that these conditions may be aggravated by their specific social prob- lems (Bradley, Summers, Wood, & Bryson, 2004;

Brereton, Tonge, & Einfeld, 2006). Yet, evidence-based therapy options for adult patients targeting social impairments, are close to non-existent (see Bishop-Fitzpatrick, Minshew, & Eack, 2013 for a systematic review). Of the few existing programs, positive findings have been reported e.g. for a care-giver-assisted social skills intervention (Gantman, Kapp, Orenski, & Laugeson, 2012) and computerized programs teaching adults with ASD to recognize emotions from faces and voices (Bölte et al., 2002; Faja et al., 2012; Golan & Baron-Cohen, 2006). While indicated effect sizes (Cohen's d) varied between 0.14 and 3.59 for improvements in social cognition, only 3 of those studies were undertaken as randomized controlled trials (Bölte et al., 2002; Faja et al., 2012; Gantman et al., 2012) including only 10, 13, and 17 adults with ASD, respectively. Of note, those social interventions target compensatory mechanisms focusing on explicit top down learning strategies. Although individuals with ASD have been shown to profit from explicit strategies, they are likely demanding cognitive resources and thus add strain in real life social situations (Glaser, 1990). Consequently it may be more promising to develop interventions that are implicit in nature and that thus depend less on explicit cognitive resources. This dissertation suggests based on the findings from basic research reviewed above in section 1.3 that interpersonal movement synchronization and imitation, given their ties to social cognition, might be a target for empathy interventions in ASD.

1.6.3 ARTS IN PSYCHOTHERAPY

One way to elicit and express emotions is through art. It is therefore not surprising that previous attempts to target empathy through interventions included reading fiction and listening to music to foster empathy in neurotypical individuals (Bal & Veltkamp, 2013; Rabinowitch, Cross, & Burnard, 2012). Interestingly, dance/movement therapy has a long tradition of using imitation and interpersonal synchronization to target social functions, an internationally widespread body- and art-based form of psychotherapy introduced to western medicine in the 1940s (Chace, 1952; Chaiklin & Wengrower, 2009). More specifically, dance/movement therapists adopt the postures and movement qualities of their clients to empathize with and strengthen their bond to their patients. This technique is considered to be one of the major contributions of dance/movement therapy to psychotherapy (Sandel, 1952). Working with children on the spectrum, Janet Adler was the first to report success with mirroring in movement (e.g. leading and following in movement) for individuals with autism in her documentary report "Looking for me" (Adler, 1970). Since then, case reports and theoretical papers followed describing similar attempts of fostering empathy through mirroring in movements (Archambeau & Szymanski, 1977; Samaritter & Payne, 2013; Scharoun, Reinders, Bryden, & Fletcher, 2014). A recent 7-week intervention study focusing on mirroring in movement showed improved self-reported social skills in young adults with autism (Koch, Mehl, Sobanski, Sieber, & Fuchs, 2014), providing some empirical evidence for this notion.

Consequently, this dissertation aims at using the findings from the targeted cross-sectional investigations of the association between imitation and synchronization and empathic functions to develop an imitation and synchronization based dance/movement intervention to foster empathic functions in adults with autism.

1.7 RESEARCH AIMS

Autism as outlined above has been described as an empathy disorder. Dissecting the broad term of empathy into cognitive and emotional aspects has allowed a more fine-grained picture of empathy functions in ASD with largely spared emotional and impaired cognitive subcomponents. Taking this line of research a step further by taking into consideration kinesthetic empathy will help to provide a better picture of ASD, to hint at potential target mechanisms for interventions, and to provide a better understanding of how kinesthetic empathy interacts with higher order empathy components in neurotypicals more generally. Since imitation as one facet of kinesthetic empathy has been investigated more extensively, the focus of this dissertation lies on synchronization and empathy.

The first aim of this dissertation (part I) was to characterize the association of interpersonal synchronization and specific subcomponents of empathy in neurotypical individuals. Towards this aim it was first attempted to create a state of the art tool to adequately assess different subcomponents of cognitive and emotional empathy (study 1). This new measure was then used to characterize the role of interpersonal synchronization in cognitive and emotional empathy by investigating neurotypical experts of interpersonal synchronization (study 2). Investigating individuals with selective superiority in synchronization was thought to pave the way for an investigation of the association between kinesthetic and cognitive/emotional empathy in individuals with selective impairment, i.e., with ASD.

The second aim of this dissertation (part II) was to characterize the association between imitation and synchronization and empathy in individuals on the autism spectrum. As a first step, neural correlates associated with ASD were reviewed with a focus on social cognition (study 3). The association of imitation and synchronization and empathic functions were then thoroughly investigated in carefully controlled cross-sectional studies (study 4 and 5). Based on those studies, study 6 made an attempt to develop and evaluate an imitation and synchronization based dance/movement intervention aiming at fostering empathic functions in individuals with ASD. Thus, each study pursued a specific aim in the context of the overarching goals of this dissertation:

Specific aim 1 (study 1). To develop and evaluate a timely measure for subcomponents of empathy. One major renewal of this measure is that it includes subcomponents of cognitive and emotional empathy that are conceptually stronger related to kinesthetic empathy than other subcomponents such as e.g. emotional mirroring.

Specific aim 2 (study 2). To provide evidence for an association between interpersonal synchronization and empathic functions in neurotypical individuals. To this end, empathy was assessed in experts of interpersonal synchronization.

Specific aim 3 (study 3). To summarize the major findings on functional and structural neural alterations associated with ASD in general and social dysfunction in particular.

Specific aim 4 (study 4): To utilize a test of automatic imitation in a much larger sample of adults with ASD than obtained previously to test whether imitative behavior and mirror neuron function are reduced in individuals with ASD.

Specific aim 5 (study 5). To characterize the role of synchronization in empathic functions in individuals with ASD compared to neurotypical individuals. In order to isolate the effect of synchronization during interaction while controlling for all other aspects of human interaction, a highly controlled minimal communication paradigm was used.

Specific aim 6 (study 6). To strengthen the notion of a causal relationship between synchronization/imitation and empathy though a longitudinal study design. By establishing the efficacy of an imitation and synchronization-based dance/movement intervention to foster empathic functions in adults with ASD, a clinical application of this mechanism is explored.

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2 PART I. THE ROLE OF INTERPERSONAL SYNCHRONIZATION IN EMPATHIC FUNCTIONS IN NEUROTYPICAL INDIVIDUALS

2.1 STUDY 1: DEVELOPMENT OF A MULTIDIMENSIONAL MEASURE OF EMPATHY[1]

2.1.1 ABSTRACT

Although research has demonstrated that empathy is comprised of dissociable components, few self-report measures have attempted to separate cognitive and emotional aspects of empathy. Here, we introduce and evaluate the *Cognitive and Emotional Empathy Questionnaire (CEEQ)*, which assesses cognitive empathy (perspective taking and mental state perception) and emotional empathy (empathic concern and emotion mirroring) separately. Internal consistency was acceptable to good for individual subscales, and scores on the CEEQ were related in a predictable way to existing empathy questionnaires and other measures of socioemotional functioning, supporting construct validity. An exploratory factor analysis largely supported the *a priori* conceptual organization of the CEEQ. We propose that the CEEQ has the potential to be a valuable tool for a comprehensive assessment of empathy, e.g., in clinical populations.

[1] This study is in preparation to be submitted as:

Savage, K.R., Teague, E. B., Koehne, S., Borod, J.C. and Dziobek, I.. A New Measure of Empathy: Psychometric Characteristics of the Cognitive and Emotional Empathy Questionnaire.

2.1.2 INTRODUCTION

Previous researchers have taken several approaches to the study of empathy (for a review, see Batson, 2009). One approach emphasizes cognitive empathy (Hogan, 1969; Kohler, 1929), which can be defined as the process of understanding another person's perspective, whereas another emphasizes emotional empathy (Hoffman, 1984; Mehrabian & Epstein, 1972), defined as an individual's emotional response to the affective state of others (Davis, 1983). Recently, researchers have embraced a multidimensional approach, proposing that both cognitive and emotional components are essential to the definition of empathy (Decety & Jackson, 2004; Dziobek et al., 2008).

Selective impairments in either emotional or cognitive empathy have been observed in various clinical populations (e.g., autism and psychopathy; Blair, 2005) and, therefore, it is important to have tools that differentiate between those components. Yet the only self-report measure that assesses empathy multidimensionally is the Interpersonal Reactivity Index (IRI; Davis, 1983). Although the IRI contains both emotional (Empathic Concern [EC] and Personal Distress [PD]) and cognitive (Fantasy [FS] and Perspective Taking [PT]) subscales, it does not take into account recent empathy research, including work on the role of perception and action coupling (e.g., Decety & Jackson, 2004; Preston & de Waal, 2002). In addition, it has been criticized for including items that measure elements less central to the construct of empathy, such as imagination (Baron-Cohen & Wheelwright, 2004).

Given the need for an up-to-date multidimensional measure, we set out to develop a new scale, the Cognitive and Emotional Empathy Questionnaire (CEEQ). The CEEQ includes empathic concern and perspective taking, two traditionally investigated aspects of empathy, and also adds two constructs to account for new conceptualizations of empathy, namely the tendency to spontaneously experience emotions that are observed in another individual (Emotion Mirroring [MIR]) and the ability to recognize and identify the emotions and mental states of other people from observable cues such as facial expressions and body language (Mental State Perception [MSP]). In addition, in an effort to increase the CEEQ's external validity, the four scales include items assessing empathy for people that are familiar to the respondent, as well as items assessing empathy for positively-valenced emotions such as happiness.

In this study, we provide data investigating the questionnaire's test-retest reliability and internal consistency. In addition, construct validity was explored with an exploratory factor analysis, and convergent and divergent validity were estimated by calculating correlations among the CEEQ and established measures of social/emotional functioning. It was expected that the CEEQ would be positively correlated with existing empathy scales, such as the IRI, particularly the corresponding constructs EC and PT. We furthermore hypothesized that emotional contagion, defined as the tendency to automatically mimic and synchronize emotional expressions with those of another person (Hatfield, Cacioppo, & Rapson, 1993), would be positively related to the CEEQ-MIR because the latter also describes a state of congruent emotion. We included objective (New York Emotion Battery; NYEB; Borod, Welkowitz, & Obler, 1992) and subjective (Toronto Alexithymia Scale; TAS-20; Bagby, Parker, & Taylor, 1994) measures of emotion perception and identification in this study and expected to find positive (NYEB) and negative (TAS) associations, especially with the CEEQ-MSP scale, as it most clearly involves the perception and identification of emotions. Moreover, we expected positive correlations between the CEEQ and personality traits that have been associated with high prosocial functioning (i.e., Extraversion; Cliffordson, 2002; Davies, Stankov, & Roberts, 1998) and negative associations between the CEEQ and personality traits and psychological constructs that have been associated with low prosocial functioning (Psychoticism, Neuroticism, and Aggression; Miller & Eisenberg, 1988). Finally, since mental flexibility is hypothesized to modulate the automatic emotional sharing mechanism between self and other, thereby allowing for a flexible shift of perspectives and empathic concern (Decety & Meyer, 2008), emotion regulation and mental flexibility were thought to be positively related to the PT and negatively related to the MIR subscales of the CEEQ.

2.1.3 METHODS AND RESULTS

2.1.3.1 Development of the CEEQ

The CEEQ is a theory-driven measure designed to assess both cognitive and emotional empathy while reflecting current research and theory. It consists of 30 self-report items, which are divided into four subscales Empathic Concern (EC), Emotion Mirroring (MIR), Perspective Taking (PT), and Mental State Perception (MSP). See Table 1 for a list of items in each subscale.

While developing test items, efforts were made to include a variety of mental states and emotions, representing both positive and negative valences. Traditionally, measures of empathy have focused on feelings of care and concern for people who are experiencing difficult situations. However, an individual can also experience an empathic response to an individual who has experienced something positive, such as feeling happy for a friend who received a job promotion. Thus, effort was made to include items representative of both positive and negative situations. In addition, idioms and figurative language were avoided in order to make the questionnaire easy to understand, particularly for individuals with communication deficits (e.g., autism spectrum disorder). To obtain a more representative estimate of empathic ability, the targets of items on the CEEQ also were varied to include both individuals whom the respondent would know and unfamiliar people, as the level of rapport with a target may affect the degree of the empathic response (Levenson & Reuf, 1997). Finally, approximately one-third of the items on the questionnaire were negatively worded to minimize response bias.

Participants respond to each item on the CEEQ using a 5-point Likert scale, ranging from “Not True at All” (0) to “Very True” (4).

The Cognitive subscales. The MSP subscale (8 items) measures the ability to recognize and identify the emotions and mental states (i.e., thoughts and intentions) of other people from facial, prosodic, gestural, and postural expressions.

An important aspect of cognitive empathy is the ability to gather and use personal information (e.g., personality traits and situational factors) to understand the perspective of others. Therefore, the CEEQ includes the PT subscale (7 items), which measures the tendency to take the perspective of another individual.

The Emotional subscales. The MIR subscale (8 items) measures the tendency to spontaneously experience emotions that are observed in another individual. This scale was developed based on current research in affective neuroscience, which suggests that simulation (i.e., sharing the emotional experience of another person) may be an important aspect of empathy and may provide the foundation for understanding others' minds (Decety & Meyer, 2008; Preston & de Waal, 2002).

The EC subscale (7 items) measures the tendency to have an other-focused, congruent emotional response to the affective state of another person.

Table 1. Factor loadings of the CEEQ items after rotation

Items	**Factors**					
	I	**II**	**III**	**IV**	**V**	**VI**
MIR1: Hearing other people laugh makes me want to laugh too.	-0.01	0.24	0.08	0.07	-0.03	0.70
MIR2: I don't really find other peoples' moods to be infectious.	-0.07	0.66	0.03	0.13	-0.01	0.47
MIR3: I tend to get nervous when I'm with someone who is scared, even though the situation would not scare me if I was alone.	-0.06	0.48	-0.08	-0.26	0.12	-0.08
MIR4: When I see someone crying because she/he is sad, it also makes me sad.	0.08	0.63	0.21	-0.19	0.09	0.23
MIR5: When I'm with someone who's experiencing a strong emotion, I start to feel that emotion too.	0.02	0.61	0.02	-0.01	0.47	0.13
MIR6: When people around me are angry, I tend to get mad too.	0.05	0.36	-0.08	-0.32	0.51	0.09
MIR7: It does not really make me feel embarrassed to see somebody else who is embarrassed.	-0.12	0.53	-0.25	0.24	-0.27	0.12
MIR8: Even without knowing the context, seeing someone who is happy makes me feel happy too.	-0.04	0.08	0.66	-0.14	0.03	0.07
EC1: I feel sympathetic towards people who are going through hard times.	0.28	0.33	0.35	-0.14	0.06	0.19
EC2: I don't often feel compassion for other people's misfortune.	0.18	0.20	0.01	0.45	-0.30	0.26
EC3: If someone I like is proud of a success, I feel happy for her/him.	0.16	-0.21	0.56	0.00	0.12	0.17
EC4: If someone I like is unhappy, I feel sorry for her/him.	0.20	0.30	0.38	0.18	0.27	0.13
EC5: My emotions are not really affected by the wellbeing of others.	0.23	0.69	0.05	0.13	-0.10	-0.14
EC6: It is satisfying for me to see good things happen to other people.	0.19	-0.02	0.74	0.07	-0.01	-0.11
EC7: I am often concerned about the feelings of people I like.	0.20	0.44	0.50	0.22	0.00	-0.15
MSP1: I am not good at telling a real smile from a fake smile.	0.55	-0.19	-0.14	0.21	0.10	0.30
MSP2: Facial expressions and gestures tell me a lot about somebody else's thoughts.	0.59	-0.05	-0.02	0.20	0.17	0.14
MSP3: I can tell what someone I know is feeling or thinking just by looking in their eyes.	0.72	0.04	-0.01	-0.04	-0.04	-0.22
MSP4: I can easily tell if someone is interested in what I am saying based on her/his body language.	0.61	0.03	0.29	-0.05	-0.15	0.00
MSP5: I am good at telling if somebody is nervous by looking at what they do with their hands or their eyes.	0.67	0.01	0.08	0.12	0.08	0.19
MSP6: I can quickly tell how someone is feeling based on subtle changes in their tone of voice	0.71	0.16	0.24	-0.02	0.12	-0.09
MSP7: Even with people I know, I find it hard to pick up on subtleties of body language	0.74	0.16	0.09	0.04	-0.03	0.19
MSP8: I am good at reading other people's facial expressions.	0.71	-0.08	0.13	0.02	0.11	-0.06
PT1: When making a judgment about somebody, I try to take into account as much personal information as possible, such as family history, cultural upbringing, and personality traits.	-0.18	0.21	-0.20	0.54	0.03	-0.41
PT2: I am not good at seeing other people's side of a disagreement.	0.10	-0.03	0.11	0.70	0.22	0.14
PT3: When I'm working with other people, I have a hard time seeing their perspective.	0.08	-0.13	-0.09	0.76	0.15	0.00
PT4: I can easily tell when someone says one thing but means another.	0.64	0.21	0.09	-0.14	0.01	-0.32
PT5: I find it easy to see things from the point of view of people I know.	-0.01	-0.07	0.00	0.15	0.64	0.07
PT6: I am usually good at predicting the behavior of people I know because I understand how they think.	0.30	0.05	0.09	0.03	0.57	-0.16
PT7: When interacting with people, I am good at taking their perspective.	-0.01	0.05	0.23	0.34	0.56	-0.08
FACTOR LABEL	**MSP**	**MIR**	**EC**	**PT self**	**PT other**	**--**

Items in bold indicate highest factor loadings that are larger than or equal to .35. Please note that if an item loaded at or above .35 on more than one factor, the item was allocated to the factor on which it loaded most highly.

2.1.3.2 Participants

A total of 104 participants were recruited, of whom six were excluded because they were not adequately fluent in English (*n* = 5) or provided incomplete data (n = 1), leaving a final sample of *n* = 98 (mean age=21.7±5.9, range=18-53; 63% female). Participants were either given course credit or $12 for their participation. Prior to testing, all participants gave informed written consent. The research protocol was approved by the Queens College Institutional Review Board.

2.1.3.3 Test-retest Reliability

To estimate test-retest reliability, 15 participants were asked to fill out the CEEQ approximately two weeks after the original testing (average time between administrations=17.5 days±3.0, range=13-24). The demographics of the 15 participants were as follows: mean age=19.8±1.7, range=18-24; 60% female. Mean intraclass correlation coefficients (ICCs (3,*k*)) were calculated between the scores obtained at each administration (see Table 2). The results indicated a high degree of reliability, with ICCs ranging from .64 to .87 (*mdn*=.80).

2.1.3.4 Internal Consistency

Internal consistency was assessed via Chronbach's alpha. Individual subscale scores were satisfactory considering the small number of items for some subscales, with values ranging from .55 to .84 (*mdn*=.64; see Table 2).

Table 2. Descriptive data for the CEEQ subscales

CEEQ Subscale	Score Range	*M(SD)*	ICCs (test-retest)	Cronbach's Alpha
Cognitive Subscales				
Mental State Perception	7-32	22.7 (5.3)	.64	.84
Perspective Taking	7-27	19.0 (3.7)	.82	.55
Emotional Subscale				
Mirroring	0-28	18.2 (5.0)	.87	.66
Empathic Concern	15-28	23.2 (3.2)	.78	.62

Abbreviations: ICC = Intraclass correlation coefficient

2.1.3.5 Convergent and Divergent Validity

Correlations with existing empathy measures. To assess convergent validity, correlations were calculated between the CEEQ and two established self-report measures of empathy: the IRI (Davis, 1983) and the Empathy Quotient (EQ; Baron-Cohen & Wheelwright, 2004), the latter of which combines cognitive and emotional aspects of empathy in one score. All correlations reported in this paper (Table 3) were Bonferroni corrected for multiple analyses (*n* = 60), so that *p*-values < .008 were considered significant. Significant correlation coefficients are summarized below.

The strongest correlations were observed between the corresponding constructs on the IRI and CEEQ (PT: *r* = .55, EC: *r* = .67). CEEQ-PT also was positively associated with IRI-EC (*r* = .32) and CEEQ- EC was associated with IRI-PT (*r* = .27). In addition, CEEQ-MIR was positively related to IRI-Personal Distress (*r* = .53) and IRI-EC (*r* = .40) and CEEQ-MSP correlated with IRI-EC (*r* = .42) and IRI-Personal Distress (*r* = .52). Finally, CEEQ-MSP was positively associated with IRI-EC (*r* = .31, see Table 3). Positive significant correlations were also observed between the EQ and all sub-scales of the CEEQ (range: .30 - .63). To further examine the convergent and divergent validity of the CEEQ, associations were assessed between the CEEQ and established measures of socio-emotional functioning (see Table 3).

Table 3. Pearson product-moment correlations among the CEEQ and other measures

	Cognitive and Emotional Empathy Questionnaire (CEEQ)			
	Perspective Taking	Mental State Perception	Empathic Concern	Mirroring
IRI – Perspective Taking (*n* = 98)	.55*	**-.01**	.27*	**.09**
IRI – Fantasy (*n* = 98)	**.20**	**-.01**	**.18**	**.24**
IRI – Empathic Concern (*n* = 98)	.32*	.31*	.67*	.42*
IRI – Personal Distress (*n* = 98)	**-.06**	**.08**	**.20**	.52*
Empathy quotient (*n* = 81)	.46*	.45*	.63*	.30*
Emotional contagion (*n* = 98)	**.14**	**.17**	**.11**	.30*
EPQ-R Extraversion (*n* = 90)	**.12**	**.25**	**.16**	**-.03**
EPQ-R Neuroticism (*n* = 90)	**-.16**	**-.07**	**.17**	.40*
EPQ-R Psychoticism (*n* = 90)	-.30*	**.01**	-.33*	**-.14**
Aggression Questionnaire (*n* = 97)	**-.17**	**.14**	**-.22**	**-.06**
TAS - Alexithymia (*n* = 80)	**-.22**	**-.26**	**-.27**	**-.01**
NYEB Emotion Perception (*n* = 93)	**.05**	**.21**	.28*	**.08**
Emotion Regulation (*n* = 97)	**..20**	**-.10**	**-.08**	**-.16**
RFFT - Mental flexibility (*n* = 92)	**-.02**	**-.07**	**-.06**	**.07**
Social Desirability (*n* = 90)	**.10**	**-.21**	**.11**	**-.10**

Abbreviations: CEEQ, Cognitive and Emotional Empathy Questionnaire; IRI, Interpersonal Reactivity Inventory; TAS, Toronto Alexithymia Scale; EPQ-R, Eysenck Personality Questionnaire - Revised; NYEB, New York Emotion Battery; RFFT, Ruff Figural Fluency Test

* Correlations significant after Bonferroni correction (*p* = 0.5/60 = .008).

Emotional contagion. To assess the relationship between emotional contagion and the CEEQ, we asked participants to complete the 15-item Emotional Contagion Scale (ECS; Doherty, 1997). Results indicated that high scores on the ECS were associated with high MIR scores on the CEEQ (*r* = .30).

Aggression and personality traits associated with prosocial/antisocial behavior. We administered the Aggression Questionnaire (Buss & Perry, 1992), as well as the Eysenck Personality Questionnaire – Revised (EPQ-R; Eysenck, Eysenck, & Barrett, 1985), which includes subscales for personality traits associated with high (Extraversion) and low prosocial functioning (Psychoticism and Neuroticism). In line with our assumptions, the CEEQ-PT correlated inversely and significantly with the Psychoticism subscale (i.e., the tendency to be inconsiderate, reckless, hostile, and impulsive; *r* = -.30). Associations with the Aggression Questionnaire were inverse (*r* = -.17), albeit not significant *(p* = .10). The CEEQ-EC also was inversely significantly correlated with the Psychoticism subscale (*r* = -.33) and Aggression Questionnaire (*r* = -.22), though the latter fell short of significance following Bonferonni correction (*p* = .03). In addition, we found a significant positive correlation between CEEQ-MIR and the Neuroticism subscale (*r* = .40). Finally, individuals who rated high on Extraversion (i.e., the tendency to be outgoing, outreaching, and talkative) also rated high on the CEEQ-MSP scale (*r* = .25), though this correlation was not significant following a Bonferonni correction.

Emotion perception and identification. Alexithymia, a personality trait characterized by difficulties identifying and describing emotions in oneself, was assessed with the Toronto Alexithymia Scale–Twenty Item Version (TAS-20; Bagby et al., 1994). Although we observed the expected inverse relationship between alexithymia and CEEQ-PT (*r* = -.22), CEEQ-MSP (*r* = -.24), and CEEQ-EC (*r* = -.27), these correlations did not reach the level of significance following the Bonferroni correction.

Objective emotion perception performance across three channels of communication (facial, prosodic, and lexical channels) was assessed using the emotion perception tasks from the New York Emotion Battery (NYEB; Borod et al., 1992, 1998). For the purposes of this study, a sum score was created for the NYEB by averaging the percentage correct for the facial, prosodic, and lexical identification tasks. Although CEEQ-MSP was positively related to the NYEB (*r* = .21) as hypothesized, the correlation was not significant. However, a significant positive correlation was observed between the NYEB and the CEEQ-EC subscale (*r* = .28).

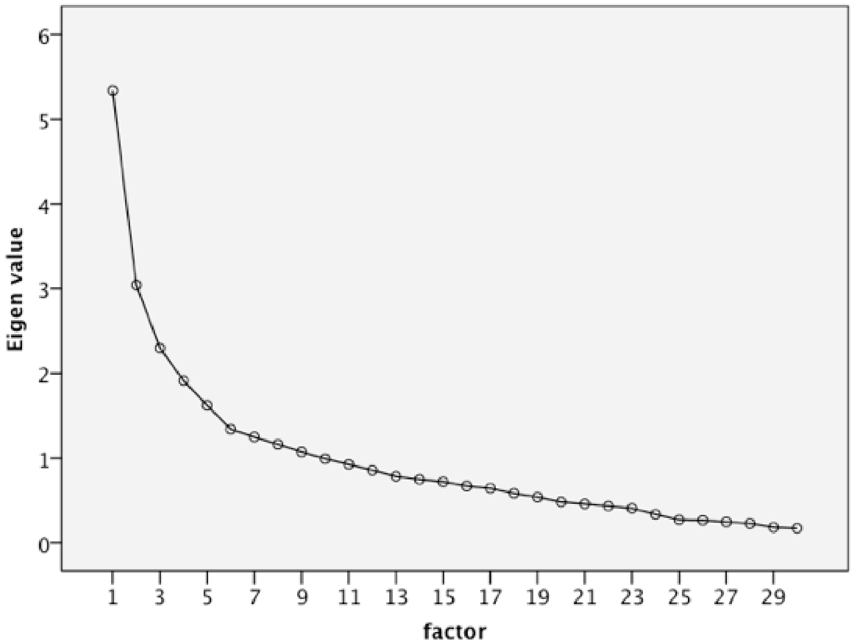
Emotion regulation and mental flexibility. We administered the Emotion Regulation Questionnaire (ERQ; Gross & John, 2003) and the Ruff Figural Fluency Test (RFFT), which asses the ability to shift cognitive sets (Ruff, Light, & Evans, 1987). Although we found the expected direction of associations between the ERQ and the CEEQ-MIR (*r* = -.16) and CEEQ-PT scales (*r* = .20), the correlations were not significant. No association emerged between the CEEQ scales and the RFFT.

Social desirability. We sought to show that scores on the CEEQ would be sufficiently independent from the tendency to answer in a socially desirable fashion. Indeed, social desirability as measured by the Crowne-Marlowe Social Desirability Scale (MC-Form C; Reynolds, 1982), showed non-significant correlations with the CEEQ scales.

2.1.3.6 Exploratory Factor Analysis

Construct validity was examined by conducting a Principal Component Analysis (PCA) with varimax rotation on an exploratory basis to inform the underlying structure of the CEEQ. The number of factors for extraction was based on Kaiser's eigenvalue criterion (eigenvalue ≥1) and evaluation of the scree plot (see Figure 1). Varimax rotation was used to enhance the interpretation of the factors. Following rotation, a 6-factor solution emerged in our sample that explained 51.9 % of the variance. The KMO was found to be 0.68, which exceeds the recommended minimum value of 0.60. Bartlett's Test of Sphericity was highly significant ($\chi^2 = 937.89$, $p < 0.001$), supporting the suitability of the data for a PCA.

Figure 2. Scree Plot



Items were included in a factor if the loading was .35 or above. If an item loaded at or above .35 on more than one factor, the item was allocated to the factor on which it loaded most highly. As can be seen in Table 1, the first factor, "Mental State Perception," accounted for 14.7% of the variance and was composed of all eight of the MSP scale items. The second factor, "Mirroring," accounted for 10.3% of the variance and was composed of five of the eight CEEQ-MIR items. The third factor, "Empathic Concern," accounted for 7.5% of the total variance and was composed of five of the eight CEEQ-EC items. Factors 4 and 5 were interpreted in combination as representing "Perspective Taking," together comprising 6 of the 7 CEEQ-PT items. More specifically, the fourth factor accounted for 7.5% of the explanatory variance on its own and was composed of three of the CEEQ-PT items, whereas the fifth factor accounted for 6.6% of the variance and was composed of three more of the CEEQ-PT items. While the two factors were interpreted together as "Perspective Taking," it is interesting to note that items on Factor 4 appeared to represent items referring to unfamiliar people (i.e., other people), whereas items on Factor 5 referred to people one knows. The sixth factor was a singleton and was, therefore, not interpreted.

2.1.4 DISCUSSION

Despite evidence indicating that empathy is a multi-dimensional construct, consisting of cognitive and emotional components (Blair, 2005; Decety & Jackson, 2004; Dziobek et al., 2008; Rogers, Dziobek, Hassenstab, Wolf, & Convit, 2007), there is a paucity of contemporary measures of this nature. Thus, the goal of the current paper was to accomplish the first steps in the development of a new multi-dimensional measure of empathy and to describe its psychometric properties.

The results of the analyses provide support for the reliability and validity of the CEEQ and directions for further work with the instrument. In terms of reliability, scores on the CEEQ were stable over a period of approximately two weeks, which must, however, be interpreted very cautiously given the small retest sample size (n = 15). Internal consistency of scores was adequate, particularly given the small number of items on subscales. Furthermore, the validity of the CEEQ as a multi-dimensional measure of empathy was supported by correlations among the subscales of the CEEQ, existing measures of empathy, and related psychological measures. Finally, support for the theoretical structure of the questionnaire was obtained from an exploratory factor analysis.

Regarding correlations between the CEEQ and existing measures of empathy, positive correlations were obtained between the established EQ and the subscales of the CEEQ, as expected, showing construct validity and indicating that the EQ is indeed a compound empathy measure that captures both emotional and cognitive aspects. Furthermore, significant positive correlations emerged between corresponding subscales of the CEEQ and the IRI. Though these questionnaires are similar, it should be noted that the CEEQ differs from the IRI in a number of important ways, which could explain why the strength of the correlation between these scales (i.e., CEEQ-PT and IRI-PT; CEEQ-EC and IRI-EC) is somewhat smaller than might be expected for corresponding scales. First, the CEEQ contains about 50% items that pertain to positively-valenced emotional situations (e.g., being happy for somebody else), whereas the IRI focuses only on negative emotions (EC) and neutral situations, respectively (PT). Moreover, situations described in the CEEQ refer, in many cases, to social interactions with individuals that are familiar to the respondent, whereas no such case occurs in the IRI. Finally, we specifically aimed at not using figurative language when wording the items of the CEEQ. The IRI, in contrast, includes terms such as "soft-hearted person," "put myself in his shoes," and "I go to pieces," which some individuals, such as those with autism spectrum disorder or alexithymic tendencies, could have difficulty understanding.

Regarding associations between non-corresponding scales of the CEEQ and IRI, we found associations between the CEEQ-MIR and the emotional subscales of the IRI (i.e., IRI-EC and IRI-Personal Distress) as expected. In addition, CEEQ-MSP and IRI-EC were moderately associated, possibly indicating that prosocially oriented individuals, who score high on EC, expose themselves more to other people and are highly motivated to understand the emotions of others, both of which may lead to an advantage in accurately perceiving mental states.

Examination of correlations among the CEEQ and measures of psychosocial function also were congruent with our hypotheses. Specifically, results indicated that emotional contagion was related exclusively to CEEQ-MIR. The fairly moderate association may be an indication that, although contagion may serve as a precursor for emotion sharing, emotion mirroring represents a different function, which may be more conscious in nature as compared to contagion. In addition, in line with our assumptions, CEEQ-PT correlated negatively with Psychoticism. Further, we found a positive correlation between CEEQ-MIR and Neuroticism, likely reflecting similarities between the tendency to "catch" somebody else's feelings and a personality style involving emotional lability. As expected, Extraversion was positively related to CEEQ-MSP.

We did not find the expected inverse relationships between alexithymic tendencies and CEEQ-MSP, possibly indicating that identifying emotions in oneself rather than in another person in the context of social interaction involves qualitatively different processes. Keeping track of two rather than one person's emotions might also place higher demands on general processing capacities given that the amount of data is doubled and given that emotional interaction involves action preparation to a higher extent than individual emotion reflecting in non-social contexts.

Contrary to our assumption, CEEQ-MSP was not significantly related to objectively measured emotion recognition performance as measured by the NYEB. This might point to poor insight regarding our awareness of our ability to recognize other's emotions; of note, inaccuracies in our assessment of our own abilities has also been described for other skills such as humor, grammar, and logic (Kruger & Dunning, 1999). It may, however, also be explained by the fact that many questions of the CEEQ tap the *motivation* to show empathy (e.g., I try to…) rather than the *level of proficiency* (e.g., I am good at…).

Although we found the expected direction of associations between emotion regulation and the MIR and PT scales, those correlations were small and did not survive Bonferroni correction. Furthermore, no association emerged between the CEEQ scales and mental flexibility (RFFT). Taken together, the results indicate that although emotion regulation and mental flexibility might be involved in some aspects of empathic functioning, their contribution seems to be rather small.

Further evidence for the construct validity of the CEEQ was obtained from an exploratory factor analysis. Results of the PCA largely support the proposed scale structure of the CEEQ with individual factors representing Mental State Perception, Mirroring, and Empathic Concern. Interestingly, the analysis also reflected the theoretical division between items referring to familiar individuals and strangers; specifically, Perspective Taking was represented across two factors, with items indicating familiar individuals represented by one factor and items referring to non-familiar others represented by another factor. Given the small sample size for the current analysis, further research is needed to confirm these results and to provide additional information about the underlying factor structure of the CEEQ, but the results of this initial analysis are encouraging.

2.1.5 CONCLUSIONS AND FUTURE DIRECTIONS

In sum, the results provide promising initial evidence for the construct validity and reliability of the CEEQ, a state-of-the-art, comprehensive assessment of both the emotional and cognitive components of empathy. This multi-faced approach may be important for conceptualizing empathic deficits in a number of psychiatric and neurological populations (e.g., autism spectrum disorders, bipolar disorder, schizophrenia, and anti-social personality disorder). Furthermore, in contrast to existing empathy measures, the CEEQ assesses subcomponents of empathy that are substantiated by recent research, avoids figurative language, includes positive emotions, and assesses empathy towards individuals with which the respondent has a close relationship.

Future investigations are needed to provide additional support for the questionnaire's psychometric properties and to address limitations of the current study. Most notably, a major limitation of the current study is the small sample size, particularly in regards to the test-retest reliability and factor analysis. In addition, it may be beneficial to consider adding more items to the CEEQ in order to increase internal consistency, although this suggestion must be weighed against the benefits of keeping a questionnaire relatively short to ease the burden on clients completing the scale. Further research is needed to address these issues. Yet, despite these limitations, the results of the current study are encouraging and provide the foundation for conducting additional studies aimed at investigating and refining the CEEQ.

In conclusion, this initial study of the multidimensional CEEQ produced promising results with respect to reliability and validity. As such, we are of the opinion that the CEEQ has the potential to be an important tool for both researchers and clinicians.

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2.2 STUDY 2: THE ROLE OF INTERPERSONAL MOVEMENT SYNCHRONIZATION IN EMPATHIC FUNCTIONS: INSIGHTS FROM TANGO ARGENTINO AND CAPOEIRA [2]

2.2.1 ABSTRACT

Although evidence points to a role for kinesthetic empathy (i.e., spontaneous interpersonal movement imitation and synchronization) in social interaction, its relationship with emotional and cognitive aspects of empathy is unknown. We compared empathy in Tango and Capoeira experts, which crucially depend on ongoing, mutual interpersonal synchronization, with empathy in practitioners of Salsa and Breakdance, respectively, which demand less interpersonal synchronization but are comparable concerning movements and setting. Kinesthetic empathy was increased in the Tango and Capoeira groups. Although no group differences in other aspects of empathy were detected, kinesthetic empathy correlated with emotional and cognitive empathy. Taken together, trait kinesthetic empathy varies in the general population, and seems increased in synchronization experts.

[2] This study has been published as:

Koehne, S., Schmidt, M. J. and Dziobek, I. (2015), The role of interpersonal movement synchronisation in empathic functions: Insights from Tango Argentino and Capoeira. *International Journal of Psychology*. doi: 10.1002/ijop.12213

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http://dx.doi.org/10.1002/ijop.12213

3 PART II. THE ROLE OF IMITATION AND SYNCHRONIZATION FOR EMPATHIC FUNCTIONS IN AUTISM SPECTRUM DISORDERS

3.1 STUDY 3: BRAIN IMAGING IN AUTISM APECTRUM DISORDERS[3]

3.1.1 ABSTRACT

In the past two decades, an increasing number of functional and structural brain imaging studies has provided insights into the neurobiological basis of autism spectrum disorders (ASD). This article summarizes pertinent functional brain imaging studies addressing the neuronal underpinnings of ASD symptomatology (impairments in social interaction and communication, repetitive and restrictive behavior) and associated neuropsychological deficits (theory of mind, executive functions, central coherence), complemented by relevant structural imaging findings. The results of these studies show that although cognitive functions in ASD are generally mediated by the same brain regions as in typically developed individuals, the degree and especially the patterns of brain activation often differ. Therefore, a hypothesis of aberrant network connectivity has increasingly been favored over one of focal brain dysfunction

3.1.2 ZUSAMMENFASSUNG

Die Erforschung der neurobiologischen Grundlagen von Autismusspektrumstörungen („autism spectrum disorders", ASD) hat in den letzten Jahren nicht zuletzt auch durch die weite Verbreitung der Magnetresonanztomographie (MRT) exponentiell zugenommen (**Fehler! Verweisquelle konnte nicht gefunden werden.**). Diese Arbeit unternimmt den Versuch einer Synopsis der relevantesten funktionell-bildgebenden Studien bei Menschen mit frühkindlichem Autismus, „High-functioning"-Autismus und dem Asperger-Syndrom, ergänzt durch konsistente Befunde zur Struktur des Gehirns. Funktionelle Studien zur Symptomtrias (Störung der sozialen Interaktion und Kommunikation, repetitives und restriktives Verhalten) und zu angenommenen zugrunde liegenden neuropsychologischen Beeinträchtigungen (Theory of Mind, Exekutivfunktionen, zentrale Kohärenz) sowie anatomische Befunde zur weißen Substanz zeichnen vermehrt ein Bild verringerter Netzwerkkonnektivität.

[3] This study has previously been published as

Dziobek, I., & Köhne, S. (2011). Brain imaging in autism spectrum disorders: A review. *Der Nervenarzt,* 82(5), 564 - 572.

The full article is available by following the link below:

https:/dx.doi.org/10.1007/s00115-010-3240-0

3.1.3 SOZIALE KOGNITION

Beeinträchtigungen in sozialer Kognition werden als ursächlich für die sozialen und kommunikativen Dysfunktionen von Menschen mit ASD gesehen (Tager-Flusberg, Joseph, & Folstein, 2001). Soziale Kognition umschreibt hierbei mentale Prozesse, die der zwischenmenschlichen Interaktion dienen, wie das Identifizieren von Gesichtern, das Erkennen von Emotionen anhand der Mimik oder die Fähigkeit, sich selbst und anderen mentale Zustände wie Emotionen, Gedanken oder Absichten zuzuschreiben. Diesen komplexen Fähigkeiten liegt ein neuronales Netzwerk des „sozialen Gehirns“ zugrunde (Brothers, 1990), das unter anderem den superioren temporalen Sulkus (STS), den fusiformen Gyrus (FG), den medialen präfrontalen Kortex (mPFC) und die Amygdala umfasst (Figure 7).

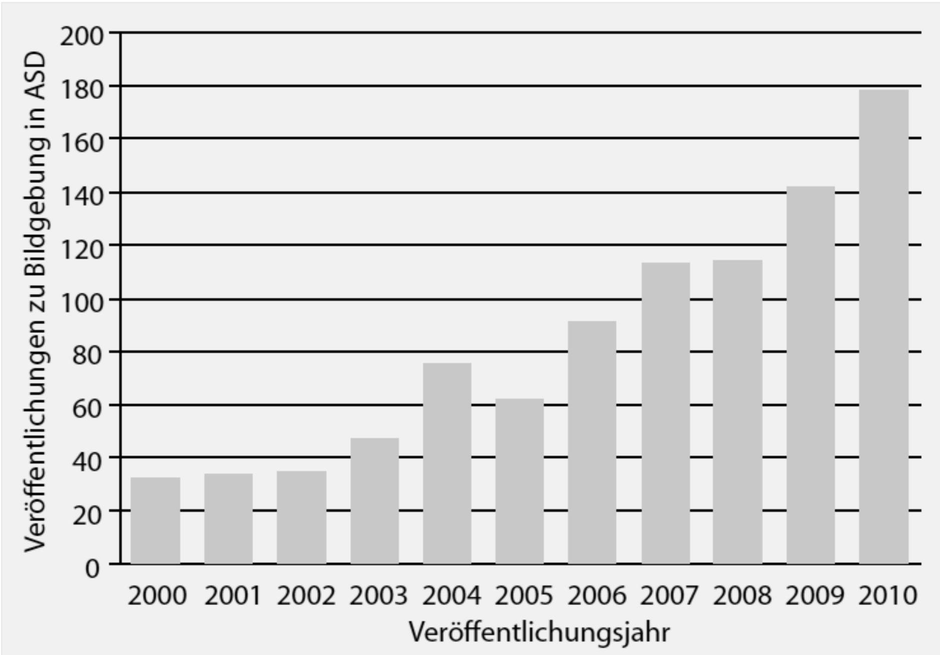

Figure 6. Anzahl veröffentlichter bildgebender Studien bei Autismusspektrumstörungen (ASD) pro Jahr. Eine PubMed-Suche wurde durchgeführt mit den Suchbegriffen „autism, autism spectrum disorders, pervasive developmental disorders” und „functional magnetic resonance imaging, neuroimaging, structural magnetic resonance imaging, diffusion tensor imaging, default mode network“.

Schwierigkeiten in der Gesichterverarbeitung gehören zu den frühsten sozialen Auffälligkeiten bei ASD (Boucher & Lewis, 1992), wobei neuere Studien diese Defizite – insbesondere bezüglich der Emotionserkennung – nicht immer bestätigen konnten (Übersicht bei Harms, Martin, & Wallace, 2010). Funktionell bildgebende Studien haben als Korrelate von beeinträchtigter Gesichterverarbeitung abweichende Aktivierungen des FG („fusiform face area“), der Amygdala und des STS identifiziert, wobei letzterem Areal eine wichtige Bedeutung bei der Interpretation dynamischer sozialer Signale wie der Blickrichtung zukommt. Mehr als ein Dutzend Studien haben bis dato eine Minderaktivierung für den FG bei der Gesichterverarbeitung gezeigt (Übersicht bei Williams et al., 2006), obwohl dieser Befund vereinzelt nicht repliziert werden konnte (Hadjikhani et al., 2004).

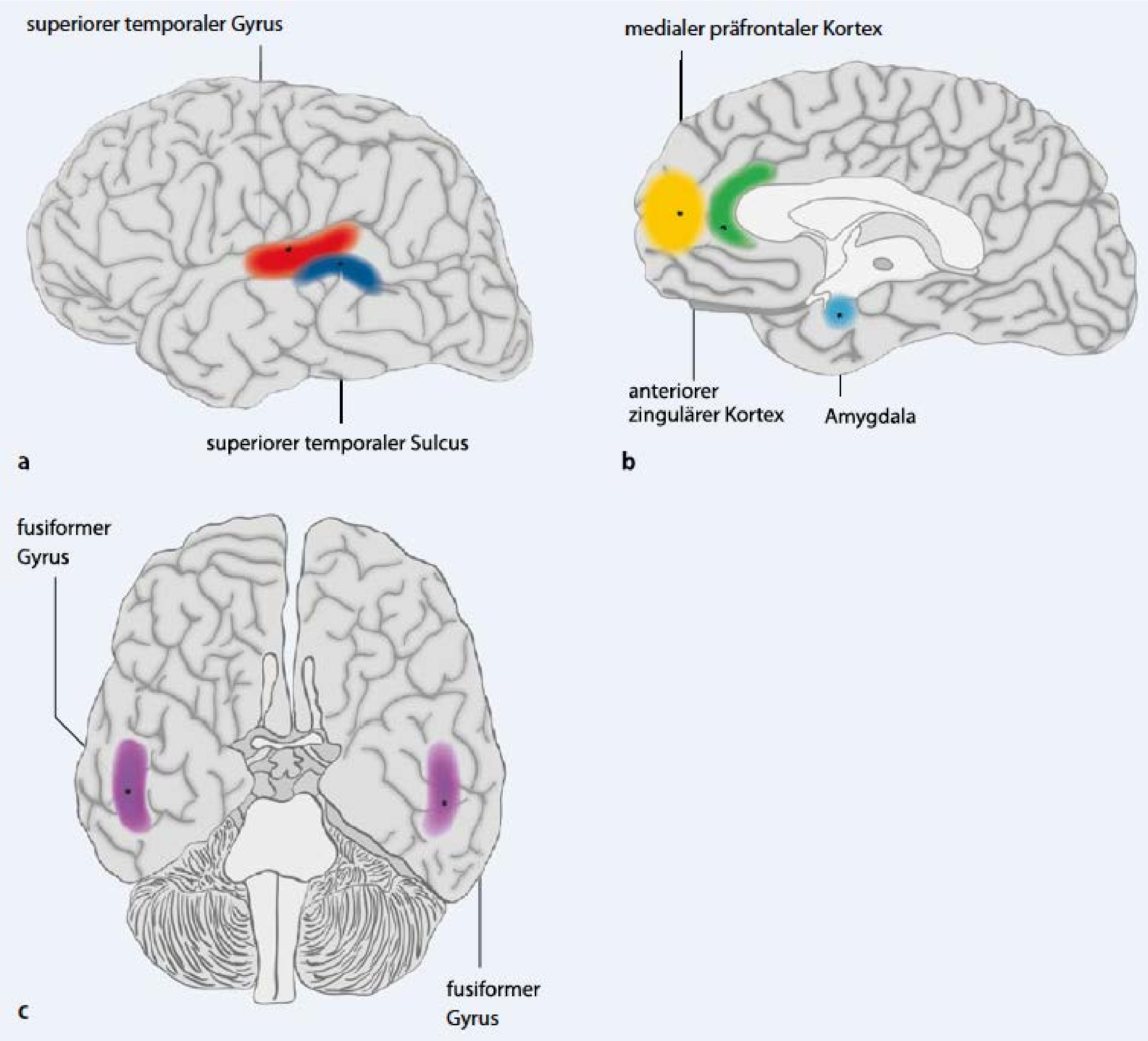

Figure 7. Das soziale Gehirn. Der superiore temporale Kortex (a) formt zusammen mit dem medialen präfrontalen Kortex und der Amygdala (b) ein neuronales Netzwerk für soziale Kognition. Perzeptueller Input stammt zum Teil aus dem fusiformen Gyrus (c), der an der Verarbeitung von Gesichtern beteiligt ist. Eine Dysfunktion dieses Netzwerks wurde mit Autismus in Zusammenhang gebracht

Eine differenzierte Betrachtung der Befunde legen vor allem Studien mit simultaner Erfassung von Augenbewegungen mittels Eyetracking-Methodik nahe. Menschen mit ASD zeigten geringere Fixationszeiten von Gesichtern und besonders Augenpartien (Kirchner, Hatri, Heekeren, & Dziobek, 2010; Klin, Jones, Schultz, Volkmar, & Cohen, 2002), für die der FG sensitiv ist. Studien, welche die Blickbewegung kontrollierten, zeigten entsprechend unbeeinträchtigte Aktivierung des FG bei der Verarbeitung neutraler Gesichter (Hadjikhani et al., 2004). Neuere Studienergebnisse legen zudem nahe, dass eine Minderaktivierung des FG bei ASD vor allem für fremde Gesichter zutrifft (Pierce & Redcay, 2008). Bei Menschen mit ASD wurden wiederholt abweichende Aktivierungsmuster der Amygdala bei der Betrachtung emotionaler Gesichter beobachtet. Während die meisten Studien eine Minderaktivierung der Amygdala berichteten (Baron-Cohen et al., 1999; Hadjikhani, Joseph, Snyder,

& Tager-Flusberg, 2007), fanden andere eine erhöhte Aktivität, die mit der Fixation der Augenregion korrelierte und als Korrelat von Aversion interpretiert wurde (Dalton et al., 2005; Kliemann, Dziobek, Hatri, Steimke, & Heekeren, 2010). Neuere strukturell bildgebende Studien verweisen auf eine verringerte Konnektivität von Amygdala und FG in ASD (Dziobek, Bahnemann, Convit, & Heekeren, 2010; Jou et al., 2011; Kleinhans et al., 2008) mit prädiktivem Wert für beeinträchtigte Gesichterverarbeitung (Dziobek et al., 2010). Verringerte FG-Aktivierung bei ASD könnte folglich mit einer Dysfunktion der Amygdala sowie einer verringerten Konnektivität der zwei Areale assoziiert sein. Neben dem FG und der Amygdala war der STS Gegenstand der Untersuchungen zur Gesichterverarbeitung bei ASD. Funktionelle Bildgebungsstudien zeigen bei Jugendlichen und Erwachsenen mit Highfunctioning-Autismus eine Minderaktivierung der STS-Region beim passiven Betrachten von neutralen Gesichtern (Hadjikhani et al., 2007) und eine geringere Modulation der Aktivität durch dynamische emotionale Gesichtsausdrücke (Pelphrey, Morris, McCarthy, & Labar, 2007). Castelli et al. (2002) berichteten eine verringerte Konnektivität des STS mit visuellen Arealen (V3) beim Attribuieren von Intentionen auf animierte geometrische Formen bei ASD. Eine Ursache für reduzierte STS-Aktivierung bei der Gesichterverarbeitung könnte folglich in der erschwerten Übertragung wichtiger visueller Bewegungsinformationen von V3 an den STS liegen (Castelli et al., 2002).

Die Fähigkeit, sich und anderen mentale Zustände zuzuschreiben, wird als Theory of Mind (ToM) bezeichnet. Eine Beeinträchtigung dieser Fähigkeit gilt als eines der wichtigsten neuropsychologischen Erklärungsmodelle für ASD (Übersicht bei Baron-Cohen, 2001). Befunde aus Tierstudien, Läsionsstudien und funktionellen Bildgebungsstudien bei typischer Entwicklung verweisen auf frontale (v. a. mPFC), limbische (Amygdala) und temporale Strukturen (Temporalpol [TP], STS, temporoparietale Übergangsregion [TPJ]) als zentral für ToM-Prozesse (Übersicht bei Adolphs, 2003). Funktionell bildgebende Studien zeigen vermehrt, dass diese Areale des ToM- Netzwerks bei Menschen mit ASD nicht gleichermaßen rekrutiert werden wie bei typisch entwickelten Menschen (Übersicht bei Domes, Kumbier, Herpertz-Dahlmann, & Herpertz, 2008). Bei einer ersten PET-Pilotuntersuchung fanden Happé et al. (1996) bei Erwachsenen mit Asperger-Syndrom zwar eine Aktivierung des mPFC, diese war jedoch mehr ventral lokalisiert als bei Kontrollprobanden. In Folgestudien zeigten Probanden mit High-functioning-Autismus und Asperger-Syndrom eine verringerte Aktivierung des mPFC bei der Bearbeitung einer auditiven ToM-Aufgabe (Nieminen-von Wendt et al., 2003) und bei einer Aufgabe mit animierten geometrischen Formen, die aufgrund ihrer Interaktion bei typisch entwickelten Probanden zu einer Attribution mentaler Zustände führen (Castelli et al., 2002). Kana et al. (2006) griffen auf das gleiche Paradigma zurück und fanden bei Erwachsenen mit High-functioning-Autismus neben einer verringerten Aktivierung ToM-relatierter Areale eine verringerte Konnektivität innerhalb des ToM-Netzwerks, insbesondere zwischen frontalen (medialer frontaler Gyrus, anteriorer Parazingulus, orbitofrontaler Gyrus) und posterioren Arealen (rechter mittlerer und superiorer temporaler Gyrus).

Gegenwärtig wird diskutiert, inwiefern Beeinträchtigungen der ToM bei ASD mit einer Dysfunktion des Spiegelneuronensystems (SNS) zusammenhängt. Spiegelneurone sind vor allem im inferioren frontalen- bzw. prämotorischen Kortex, aber auch im parietalen Kortex lokalisierte Nervenzellen, die bei der Beobachtung von Bewegung anderer die gleichen Potenziale auslösen wie bei der entsprechenden eigenen Bewegung. Obwohl Spiegelneurone bisher nur in Tierversuchen eindeutig nachgewiesen wurden, wird vermutet, dass sie auch beim Menschen zu finden sind und u. a. Funktionen der Imitation und Verarbeitung mimischer Signale sowie der Empathiefähigkeit zugrunde liegen (Rizzolatti & Craighero, 2004). Da sowohl Imitationsverhalten als auch die Verarbeitung von Mimik bei ASD beeinträchtigt sind, wurde spekuliert, dass ein defizitäres Spiegelneuronensystem zur Symptomatik von ASD beitragen könnte. Einige funktionelle Bildgebungsstudien stützen diese Hypothese. Sie fanden eine verminderte Aktivierung des inferioren frontalen Kortex bei der Imitation von emotionalen Gesichtsausdrücken (Dapretto et al., 2006; Williams et al., 2006) sowie beim Bearbeiten einer Empathieaufgabe (Schulte-Rüther et al., 2011) bei Jugendlichen und Erwachsenen mit ASD. Eine zunehmende Zahl behavioraler und neurophysiologischer Forschungsstudien spricht jedoch gegen eine generelle Dysfunktion des SNS-Systems bei Menschen mit ASD (Bird et al., 2010; Bird, Leighton, Press, & Heyes, 2007; Dinstein et al., 2010; Fan, Decety, Yang, Liu, & Cheng, 2010; Press, Richardson, & Bird, 2010).

Volumetrische Daten zu FG, Amygdala und STS in ASD sind divergent (Übersicht bei Stigler, McDonald, Anand, Saykin, & McDougle, 2010). Für den FG und die STS- Region wurden sowohl unveränderte als auch vergrößerte und verkleinerte Volumina berichtet. Die Abweichungen im Amygdalavolumen scheinen einen altersabhängigen Verlauf zu nehmen: Während die Amygdala in der Kindheit ein vergrößertes Volumen aufweist, zeigt sie während der Adoleszenz nicht die gleichen Wachstumsprozesse wie bei typisch entwickelten Kindern, sodass im Erwachsenenalter keine Volumenunterschiede festzustellen sind (Übersicht bei Amaral, Schumann, & Nordahl, 2008). Auf strukturelle Auffälligkeiten des SNS weist eine MRT-Studie hin, die bei Erwachsenen mit High-functioning Autismus eine lokale Reduktion des Volumens der grauen Substanz im inferioren frontalen Kortex, im inferioren Parietalkortex und im STS fand (Hadjikhani, Joseph, Snyder, & Tager-Flusberg, 2006). Die reduzierte kortikale Dicke des SNS korrelierte zudem mit der Symptomschwere von ASD.

Zusammengefasst ist eine Minderaktivierung des FG bei der Gesichterverarbeitung der bislang konsistenteste Befund zu neuronalen Korrelaten der sozialen Kognition bei ASD, wobei es die Einflüsse von Aufmerksamkeit und Blickrichtung sowie der Vertrautheit der Gesichter noch besser zu charakterisieren gilt. Menschen mit ASD zeigen darüber hinaus funktionelle und strukturelle Auffälligkeiten in Arealen, die mit der ToM und dem SNS in Zusammenhang gebracht werden. Eine eher heterogene Befundlage macht jedoch deutlich, dass ASD nicht auf eine generelle Dysfunktion des Spiegelneuronensystems zurückgeführt werden können.

3.1.4 SPRACHE

Obwohl linguistische Auffälligkeiten bei Menschen mit ASD von einem völligen Fehlen funktioneller Sprache bis zu außergewöhnlichen Sprachfähigkeiten reichen, zeigen die meisten Menschen mit ASD zumindest einen gewissen Grad an Beeinträchtigung in der semantischen, syntaktischen oder pragmatischen Sprachverarbeitung (Übersicht bei Groen, Zwiers, van der Gaag, & Buitelaar, 2008). Funktionelle MRT-Studien (fMRT) haben begonnen, die neuronalen Grundlagen der Sprachdefizite zu erforschen und dabei den inferioren frontalen Gyrus (IFG, inklusive Broca-Areal) und das Planum temporale (PT, inklusive Wernicke-Areal) fokussiert. Menschen mit ASD scheinen bei der Verarbeitung von Sprache temporale Areale stärker und frontale Areale schwächer zu rekrutieren als Kontrollprobanden und zeigen zudem eine verringerte Konnektivität innerhalb des Sprachverarbeitungsnetzwerks. Ein solches Aktivierungsmuster wurde unter anderem bei der Verarbeitung syntaktisch komplexer Sätze beobachtet (Just, Cherkassky, Keller, & Minshew, 2004). Während eine stärkere Aktivierung des Wernicke-Areals bei Menschen mit High-functioning-Autismus dabei als Hinweis auf eine tiefere Verarbeitung der Bedeutung einzelner Worte interpretiert wurde, scheint die geringere Aktivierung des Broca-Areals die beeinträchtigte Fähigkeit widerzuspiegeln, einzelne Wortbedeutungen in eine übergreifende konzeptuelle und syntaktische Struktur zu integrieren. Die Ergebnisse weisen damit eine Parallele zur Theorie der schwachen zentralen Kohärenz (s. unten) auf, die davon ausgeht, dass Menschen mit ASD Details bevorzugen – und möglicherweise auf Kosten einer Gesamtintegration der Information – verarbeiten. Es wird vermutet, dass Menschen mit ASD temporäre neuronale Netzwerke, die während der Sprachverarbeitung gebildet werden, weniger flexibel neu gruppieren. Dafür spricht, dass die Verarbeitung verschiedener Aspekte einzelner Worte (z. B. semantisch vs. perzeptuell) kaum zu Unterschieden in neuronalen Aktivierungsmustern führt (Harris et al., 2006). Die weniger flexible Neugruppierung neuronaler Netzwerke könnte durch eine abweichende Konnektivität der sprachverarbeitenden Areale bedingt sein.

Insgesamt scheinen sich Menschen mit ASD bei der Sprachverarbeitung vermehrt auf visuelle Informationen zu stützen, wofür Ergebnisse sprechen, die eine stärkere Rekrutierung visueller Areale bei Auf- gaben zur semantischen Kategorisierung und bei der Verarbeitung abstrakter Sätze zeigen (Gaffrey et al., 2007; Kana et al., 2006). Zugleich spricht eine verringerte Konnektivität posteriorer Hirnareale mit frontalen Sprachzentren und Arealen zur Verarbeitung räumlicher Information für eine mangelnde Integration von Sprache und visueller Information (Kana et al., 2006; Sahyoun, Belliveau, & Mody, 2010). Abweichungen in der Aktivierung des Broca- und Wernicke-Areals bei ASD verweisen zusammengenommen auf Defizite in der Integration einzelner Wortbedeutungen in einen größeren Kontext. Auch bezüglich der Sprachverarbeitung setzt sich zunehmend die Hypothese einer geringeren Konnektivität rekrutierter kortikaler Netzwerke gegen die Annahme einzelner betroffener Gehirnareale durch.

3.1.5 EXEKUTIVFUNKTIONEN UND REPETITIVES VERHALTEN

Exekutivfunktionen (EF) stellen ein multidimensionales Konstrukt dar, das kognitive Flexibilität, Reaktions- und Antworthemmung, Arbeitsgedächtnis, Problemlösen, Planen und Interferenzanfälligkeit einschließt. Es wurde vorgeschlagen, dass Beeinträchtigungen in EF einen plausiblen Erklärungsansatz für die ASD-typischen begrenzten und repetitiven Verhaltensweisen bieten (Russo et al., 2007). Tatsächlich legen die Befunde bei ASD ein Profil exekutiver Dysfunktionen nahe mit Schwächen bei kognitiver Flexibilität, Planen und Denkflüssigkeit, bei relativen Stärken der Reaktionshemmung und des Arbeitsgedächtnisses. Trotz weitestgehend unauffälliger Leistung bei Aufgaben zur Reaktionshemmung haben Bildgebungsstudien gezeigt, dass bei Menschen mit ASD im Vergleich zu Kontrollprobanden unterschiedliche Netzwerke aktiviert werden, wenn sie Go-/No-Go-Aufgaben bearbeiten. Abweichende Aktivierungsmuster wurden für frontale und parietale Gehirnareale (Schmitz et al., 2006) sowie in Zingulum, Insula und inferiorem frontalem Gyrus (Kana, Keller, Minshew, & Just, 2007) gefunden. Zudem verweisen Studien neueren Datums auf eine reduzierte funktionelle Konnektivität zwischen Zingulum und frontalem Augenfeld (Agam, Joseph, Barton, & Manoach, 2010).

Eine Reihe von Bildgebungsstudien hat sich dem Arbeitsgedächtnis bei ASD gewidmet. Die Gruppe um Koshino (2007) fand verringerte Aktivierung in links präfrontalen und rechts posterior temporalen Arealen bei einem Paradigma zum Arbeitsgedächtnis mit Gesichtsstimuli. Funktionelle Konnektivitätsanalysen verwiesen hier zudem auf geringere Vernetzung mit frontalen Arealen bei unveränderter Konnektivität mit parietalen Arealen, was auf ein unterschiedliches Netzwerk für Prozesse des Arbeitsgedächtnisses hindeutet. Studien zur kognitiven Flexibilität und zum Planen bei ASD zeigten bei beeinträchtigten Leistungen eine Mehraktivierung des rechten inferioren und linken medialen Parietalkortex im Vergleich zu Kontrollpersonen (Schmitz et al., 2006) und eine verringerte Konnektivität zwischen frontalen und parietalen Arealen (Just, Cherkassky, Keller, Kana, & Minshew, 2007). Eine strukturell bildgebende Untersuchung verweist auf die Integrität frontalen Gehirnvolumens bei gleichzeitiger Beeinträchtigung in typischen Aufgaben zum Planen (Griebling et al., 2010), was gegen eine auf den frontalen Kortex begrenzte Dysfunktion und ebenfalls für die These von defizitären Netzwerken spricht.

Zusammenfassend lassen die Ergebnisse bildgebender Studien bei ASD unterschiedliche neuronale Grundlagen für EF annehmen als bei typisch entwickelten Personen. Dabei scheint sowohl das Muster der aktivierten Gehirnareale, vor allem aber deren Konnektivität verändert zu sein, was als Hinweis auf die Anwendung kompensatorischer Strategien gewertet werden kann.

3.1.6 ZENTRALE KOHÄRENZ

Menschen mit ASD nehmen Reize in der Umwelt eher einzelheitlich, isoliert und detailliert statt gestalthaft, geschlossen und ganzheitlich wahr. Eine Theorie solcher Abweichungen bei Autismus wurde durch Frith (1989) mit dem Konzept der „schwachen zentralen Kohärenz“ (ZK) vorgestellt. Dieses Modell geht von einem Defizit kontextorientierter, globaler Wahrnehmung und Informationsverarbeitung aus. Es stellt ein Erklärungsmodell dar für die guten Leistungen von Menschen mit ASD beim Mosaiktest (MT) der Wechsler-Intelligenz-Skalen und beim Embedded Figures Test (EFT) (Shah & Frith, 1983, 1993). Beim EFT ist der Proband aufgefordert, eine einfache Form in einer komplexen Graphik zu finden, in der sie eingebettet ist. Während die meisten empirischen Arbeiten zur detailorientierten Verarbeitung von visuell-räumlichen Stimuli vorliegen (Übersicht bei Dakin & Frith, 2005), zeigen auch eine Reihe von Arbeiten aus dem Bereich der Sprach-, Bewegungs-, Gesichter- und Musikverarbeitung veränderte Wahrnehmungsprozesse dieser Art bei ASD (Übersicht bei Francesca Happé & Frith, 2006). Als neurobiologische Grundlage globaler Wahrnehmung wurden anatomische Konnektivität zwischen kritischen Arealen sowie funktional ausreichende Synchronisation des Feuerns von Neuronen angenommen (Engel, Fries, & Singer, 2001; Sporns, Chialvo, Kaiser, & Hilgetag, 2004). Bei ASD sind solche grundsätzlichen Voraussetzungen womöglich beeinträchtigt (Uhlhaas & Singer, 2007). Mittels Diffusions-Tensor-Bildgebung wurde jüngst insbesondere mangelnde Konnektivität zwischen Corpus callosum, Gyrus temporalis superior und Temporalstamm berichtet (Alexander et al., 2007; Lee et al., 2007). Andere Theorien, die sowohl von Unterkonnektivität (distal) als auch von Überkonnektivität (lokal) beim Zustandekommen lokal orientierter Wahrnehmung ausgehen (Belmonte et al., 2004), fanden bislang keine ausreichende empirische Absicherung (Sundaram et al., 2008).

Einige funktionelle Aktivierungsstudien wurden zur Verarbeitung des EFT durchgeführt: Ring et al. (1999) beobachteten vermehrte okzipitotemporale Aktivität bei ASD und vermehrte präfrontale Aktivität bei den Kontrollpersonen. Zu vergleichbaren Ergebnissen kam eine Studie neueren Datums (Damarla et al., 2010), die zudem eine verringerte kortikale Konnektivität zwischen frontalen und parietookzipitalen Arealen berichtete. Die Autoren schlussfolgerten, dass sich die kognitiven Strategien der Gruppen bei der Aufgabenbearbeitung qualitativ unterscheiden. Während die Kontrollprobanden stärker das Arbeitsgedächtnis zur Problemlösung nutzen, deutet die erhöhte Aktivität im visuellen System der Personen mit ASD vor allem auf Prozesse der Objektanalyse hin. In einer ähnlichen Arbeit von Manjaly et al. (2007) ergaben sich bei der Verarbeitung des EFT in der Kontrollgruppe Aktivierungen parietal und prämotorisch links, während Probanden mit ASD verstärkt im primären visuellen Kortex rechts und beidseitig extrastriatal aktivierten. Bölte et al. (2008) untersuchten die Aktivierungsmuster im striatalen und extrastriatalen visuellen Kortex bei ASD und gesunden Kontrollprobanden während der Bearbeitung des MT. Die ASD-Gruppe zeigte verringerte Aktivierung im rechten ventralen Quadranten der V2 der zweiten retinotopen Region im visuellen Kortex, die vorwiegend für Form- und Figurgrundstimuli selektive Neuronen enthält.

3.1.7 KONNEKTIVITÄT

Neben der Untersuchung einzelner Gehirnareale wird in der bildgebenden ASD- Forschung zunehmend die Konnektivität zwischen verschiedenen Regionen fokussiert. Inspiriert wurde diese Forschung unter anderem durch das neuropsychologische Model der zentralen Kohärenz. Happé und

Frith (2006) schlagen vor, dass Konnektivitätsunterschiede von kortikalen und subkortikalen Arealen zu einem detailfokussierten kognitiven Stil führen könnten. Eine zunehmende Anzahl an funktionell bildgebenden Studien liefert unter Zuhilfenahme neuropsychologischer Untersuchungsparadigmen Hinweise für diese Annahme (Just et al., 2004; Kana, Keller, Cherkassky, Minshew, & Just, 2009). Abweichende Konnektivitätsmuster konnten zudem innerhalb des sog. Ruhezustandsnetzwerks („default mode network") gezeigt werden, das aktiviert ist in Augenblicken innerer Ruhe, wenn keine koordinierten, absichtsvollen Aufgaben bearbeitet werden (Übersicht bei Stigler et al., 2010). Auf abweichende Konnektivität deuten des Weiteren sowohl der veränderte Wachstumsverlauf des Gesamthirnvolumens hin (Redcay & Courchesne, 2005) als auch volumetrische Messungen der weißen Substanz (Chung, Dalton, Alexander, & Davidson, 2004) und Befunde aus der Diffusions-Tensor-Bildgebung (DTI) zur verringerten Integrität der weißen Substanz (Übersicht bei Stigler et al., 2010). Courchesne et al. (2005) schlagen vor, dass die verringerte Konnektivität kortikaler Areale mit einer lokal desorganisierten und inadäquat selektiven Überkonnektivität des Frontallappens einhergeht, was jedoch weiterer Bestätigung bedarf. Während einerseits reduzierte Konnektivität neuropsychologische Auffälligkeiten bei ASD erklären könnte, ist zu vermuten, dass andererseits veränderte Umwelteinflüsse und Erfahrungen zu Abweichungen in der Konnektivität führen, sodass von einem bidirektionalen Zusammenhang auszugehen ist.

3.1.8 FAZIT

Die steigende Anzahl funktionell und strukturell bildgebender Studien in den letzten 2 Jahrzehnten hat maßgeblich zum Verständnis der neurobiologischen Basis von Autismus beigetragen. Hierbei zeigen die vorliegenden Ergebnisse, dass obwohl kognitive Funktionen bei ASD generell durch die gleichen Gehirnareale vermittelt werden wie bei typisch entwickelten Menschen, sich vor allem die Aktivierungsmuster häufig unterscheiden. Zunehmend setzt sich daher die Hypothese einer geringeren Konnektivität rekrutierter kortikaler Netzwerke gegen die Annahme einzelner betroffener Gehirnareale durch. Zu berücksichtigen ist jedoch, dass die meisten Studien Menschen mit High-functioning-Autismus untersuchen, sodass die Generalisierbarkeit der Aussagen auf andere Funktionsbereiche des Autismusspektrums zu zeigen bleibt. Zukünftige Studiendesigns sollten verstärkt frühkindlichen Autismus einbeziehen sowie longitudinale Formate und multimethodale Ansätze berücksichtigen. Eine weitere wichtige Aufgabe zukünftiger Forschung besteht in der Integration von Bildgebungsbefunden mit klinischen, neuropsychologischen und molekulargenetischen Befunden.

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3.2 STUDY 4: IS IMITATION REALLY IMPAIRED IN INDIVIDUALS WITH AUTISM?[4]

3.2.1 ABSTRACT

A lack of imitative behavior is frequently described as a core feature of Autism Spectrum Disorders (ASD), and is consistent with claims of mirror neuron system dysfunction in these individuals. Previous research has questioned this characterization of ASD however, arguing that when tests of automatic imitation are used - which do not require higher-level cognitive processing - imitative behavior is intact or even enhanced in individuals with ASD. In Experiment 1 60 adult individuals with ASD and a matched Control group performed an automatic imitation task in which they were required to perform an index or a middle finger lift while observing a hand making either the same, or the alternate, finger movement. Both groups demonstrated a significant imitation effect whereby actions were executed faster when preceded by observation of the same action, than when preceded by the alternate action. The magnitude of this 'imitation effect' was statistically indistinguishable in the ASD and Control groups. Experiment 2 utilised an improved automatic imitation paradigm to demonstrate that, when automatic imitation effects are isolated from those due to spatial compatibility, increasing autism symptom severity is associated with an increased tendency to imitate. Notably, there was no association between autism symptom severity and spatial compatibility, demonstrating the specificity of the link between ASD symptoms and increased imitation. These results provide evidence against claims of a lack of imitative behavior in ASD, and challenge the 'Broken Mirror Theory of Autism'.

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3.3 STUDY 5: THE ROLE OF INTERPERSONAL SYNCHRONY FOR EMPATHY IN INDIVIDUALS WITH AND WITHOUT AUTISM[5]

3.3.1 ABSTRACT

This study investigated the effect of unilateral interpersonal synchrony on empathy in two simple leader-follower finger tapping communication tasks in individuals with and without autism spectrum disorder (ASD). In unilateral synchronization, one individual within a dyad (the follower) unilaterally adjusts his or her movements to entrain to the movements of the other (the leader). *Perceived* synchrony, i.e., being followed by a synchronous virtual partner when leading an interaction, increased subjective cognitive empathy (understanding other's mental states) towards the virtual follower in participants without, but not those with, ASD. In the ASD group, the degree of *produced* synchrony, i.e., entrainment to the virtual leader when following in an interaction, was associated with higher cognitive empathy performance as measured with external objective tasks. These results point to a mediating role for interpersonal synchronization in cognitive empathy, a mechanism that seems attenuated, yet not absent, in ASD.

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3.3.2 INTRODUCTION

A lack of empathy is one of the key characteristics of individuals with autism spectrum disorder (ASD, Baron-Cohen and Wheelwright 2004), a psychiatric condition characterized by impaired development in social interaction and communication (American Psychiatric Association, 2013). While results for impairments in emotional empathy, i.e., the capacity to share the feelings of others, have been somewhat inconsistent (Dziobek et al., 2008), it has repeatedly been shown that individuals with ASD have difficulties in cognitive empathy, i.e., in attributing mental states including thoughts, intentions, and emotions to others (Baron-Cohen, Leslie, & Frith, 1985; Baron-Cohen, 2001; Dziobek et al., 2006; Frith & Happé, 1994).

A proposed mechanism for the empathy deficits observed in ASD is coming from imitation impairments (for an overview, Ramachandran & Oberma, 2006). It is assumed that spontaneously imitating observed mental states allows for a direct first person access to that state, thus it can follow that impairments in imitation also affect empathy functions (Gallese & Goldman, 1998; Oberman & Ramachandran, 2007). Findings from neurotypical (NT) individuals support the link between imitation and social cognition showing that imitation of postures, mannerisms, facial expressions, and other behaviors can occur spontaneously with positive social consequences, for instance: liking, emotion recognition, generosity, and reduced racial prejudice (Chartrand & Bargh, 1999; Dimberg, Thunberg, & Elmehed, 2000; Inzlicht, Gutsell, & Legault, 2012; Stel & van Knippenberg, 2008; van Baaren, Holland, Steenaert, & van Knippenberg, 2003). However, whether or not imitation difficulties contribute to the deficits in cognitive empathy typical for individuals with ASD is still a matter of debate (Bird, Leighton, Press, & Heyes, 2007; Hamilton, Brindley, & Frith, 2007).

Although most of the research investigating the link between motor matching and social cognition has focused on imitation, similar effects have been reported for temporal coordination of movements, i.e., interpersonal synchrony, such as walking in lock-step or joint drumming, which led to the assumption that synchronization and imitation reflect two facets of interpersonal coordination (Chartrand & Lakin, 2013). Similar to imitation, interpersonal synchrony can occur spontaneously (Issartel, Marin, & Cadopi, 2007). For instance, Richardson et al. (2007) found that visually-coupled individuals sitting side-by-side in rocking chairs spontaneously synchronize their movements even if the natural period of the rocking chair was different. Both, in-phase and anti-phase synchrony, have been shown to occur spontaneously and to be equally stable (Richardson et al., 2007; van Ulzen, Lamoth, Daffertshofer, Semin, & Beek, 2008). In addition, a growing body of research provides evidence for social consequences of interpersonal synchrony by showing associations with greater rapport, pro-social behavior, and cooperation (Bernieri, 1988; Hove & Risen, 2009; Kirschner & Tomasello, 2010; Valdesolo, Ouyang, & DeSteno, 2010; Wiltermuth & Heath, 2009).

In an effort to further break down the complex process of interpersonal synchronization, previous research has focused on unilateral (in contrast to reciprocal) synchronization (Cacioppo et al., 2014). In unilateral synchronization, one individual within a dyad (the follower) unilaterally adjusts his or her movements to entrain to the movements of the other individual (the leader) within the dyad, where the leader moves periodically but does not adjust his or her movements in reciprocation to promote synchrony. The more passive experience of synchrony in the leader role has been referred to as *perceived synchrony*, whereas the experience of the follower, who actively adjusts his or her movements to entrain to the movements of the leader, can be described as *produced synchrony*. Interestingly, similarly to produced synchrony, perceived synchrony has also been found to increase feelings of affiliation (Cacioppo et al., 2014).

While imitation and interpersonal synchronization share certain features, they also differ in important ways. As a result they are considered as two different processes. Whereas imitation always yields behaviors that are similar in form and close in timing, synchronization may or may not yield behaviors that are similar in form. Although behaviors are temporarily close in imitation, timing of behavior is critical to determining whether one person behaves synchronously with others (Chartrand & Lakin, 2013). Interestingly, in addition to imitation deficits, less spontaneous synchronization and difficulties voluntarily synchronizing with another person have recently been reported for individuals with ASD and have been suggested to also contribute to their social deficits (Fitzpatrick, Diorio, Richardson, & Schmidt, 2013; Gowen & Miall, 2005; Marsh et al., 2013). However, associations between synchronization and cognitive and emotional empathy have not yet been investigated directly in individuals with or without autism.

We therefore assessed the potential deficit in *producing* interpersonal synchronization, i.e., entrainment to a virtual leader when following in an interaction, in adults with ASD, and its relation to individual cognitive empathy performance. To this end we investigated whether a subject would synchronize his behavior more with a putative human partner than with a non-human partner (computer), assuming that the social framing would increase *produced* synchronization in neurotypical individuals but not those with ASD. This hypothesis was based on previous research showing a so-called animacy or human imitation bias in non-autistic individuals, i.e. increased automatic imitation when observing human movements compared to a robot (Bird et al., 2007; Kilner, Paulignan, & Blakemore, 2003; Press, Bird, Flach, & Heyes, 2005; Press, Gillmeister, & Heyes, 2007). In addition, we attempted to relate *produced* synchronization behavior to objectively measured individual cognitive empathy functions. We assumed that higher tendencies to synchronize with a human partner correlate with higher cognitive empathy performance.

We also assessed the effect of *perceived* synchrony on empathy through examining whether an individual, who is followed by somebody in a highly synchronous way, reports higher cognitive and emotional empathy towards that specific partner than when followed by somebody in a less synchronous way. In this context, cognitive and emotional empathy were assumed to vary between specific contexts, i.e., at the state level (de Vignemont & Singer, 2006; Zaki, 2014).

3.3.3 MATERIAL AND METHODS

3.3.3.1 Participants.

Twenty adults with ASD (16 men, mean age = 33.0) and 22 NT participants (16 men, mean age = 32.5) with no reported history of psychiatric or neurological disorders participated in the study (see Table 8 for details). The groups were comparable in age ($t(40) = -.19$, $p = .85$), fluid intelligence (as assessed through a strategic reasoning test (Leistungsprüfsystem (LPS), subscale 4, Horn, 1962; $t(39) = -.75$, $p = .46$) and crystalline intelligence as assessed through a German vocabulary test (Wortschatztest (WST), Schmitz & Metzler, 1992, $t(33.85) = - 1.28$, $p = .21$). ASD participants were recruited through the autism outpatient clinic of the Charité - Universitätsmedizin Berlin, or were referred by specialized clinicians. All of the participants were diagnosed according to DSM-IV criteria for Asperger syndrome and autism without mental retardation (American Psychiatric Association, 1994). Diagnosis included the Autism Diagnostic Observation Schedule (*n* = 18, Lord, Rutter, DiLavore, & Risi, 2002), and the Autism Diagnostic Interview – Revised (*n* = 12, ADI-R; Lord, Rutter, & Le Couteur, 1994) if parental informants were available. Additionally, diagnoses were confirmed with the Asperger Syndrome and High-Functioning Autism Diagnostic Interview (*n* = 17, ASDI; Gillberg, Gillberg, Råstam, & Wentz, 2001). All of the participants gave written informed consent prior to their participation, and the study was approved by the ethics committee of the German Society for Psychology (DGPs).

Table 8. Demographic and diagnostic information for participants with ASD and controls of study 5

Demographic and diagnostic measures	ASD group			NT control group			
	N	*M*	*SD*	*N*	*M*	*SD*	*p*
Sex (female : male)	4:16	-	-	6:16	-	-	-
Age	20	33	9.4	22	32.5	8.9	.85
Crystalline intelligence (WST-IQ)	20	112.8	18	21	106.5	12.6	.21
Fluid intelligence (LPS- IQ subscale 4)	20	121.9	10	21	119.6	10.3	.46
ADOS symptom severity	18	10.3	3.5	-	-	-	-
ASDI symptom severity	17	41	3.9	-	-	-	-

Abbreviations: ASD = Autism spectrum disorder, NT = neurotypical control, WST = Wortschatztest, LPS = Leistungsprüfsystem, ASQ = Autism Spectrum Quotient, ADOS = Autism Diagnostic Observation Schedule, ASDI = Asperger Syndrome and High Functioning Autism Diagnostic Interview.

3.3.3.2 Minimal Synchrony Paradigm

Experimental design. Participants were asked to engage in a tapping interaction similar to using Morse code for communication in which a simple light signal (produced by a single tap on the space bar) replaced an acoustic signal as the carrier of a "message". Participants were told that the study was designed to investigate minimal non-verbal communication for potential use in cell phone applications. For each round one participant would be assigned the role of the leader, who would be responsible for creating a series of light signals at a designated rate (fast: 1 beat every 1 sec; slow: 1 beat every 1.5 sec), and the other participant would be assigned the role of the follower, who would be responsible for responding by creating a light signal following each signal produced by the leader. The graphical interface contained two circle-like avatars (subject and partner). Light signals were visually represented by a simple animation where the circle-shaped avatar acquired a red glow. Unbeknownst to the participants, the ostensible partner in both the leader and follower rounds was always a computer program. Substantial effort was made to disguise the aims of the study: the cover story framed the aim of the study in terms of "communication" so that neither the target concepts of cognitive and emotional empathy nor related constructs such as liking or affiliation were mentioned. All individual difference measures of empathy were administered in a separate testing session. Additionally participants were never asked to synchronize their movements to their partners' movements. In contrast to previous research (Cacioppo et al., 2014), subjective synchrony was not probed during the experiment.

Leader task. The leader task, adapted from (Cacioppo et al., 2014), was designed to assess the effect of *perceived* interpersonal synchrony on cognitive and emotional empathy. Participants were assigned the role of the leader and instructed to send a light signal in either fast or slow tempo, while the computer program generated a light signal that followed each participant's signal and was manipulated to be synchronous or asynchronous. After each interaction round, participants entered ratings of how much they understood the thoughts and intentions of their partner (cognitive empathy). In addition, three items captured emotional empathy including a general item asking "how much they shared the feeling of their partner", one item asking for positive emotions ("seeing my partner happy would make me happy too") and one for negative emotions ("seeing my partner sad would make me sad too"). The experimental design when the participant was the leader was a synchrony (synchronous or asynchronous) x group (ASD or NT) mixed-model factorial design with the first factor (synchrony) manipulated within participants. Subjective ratings of cognitive and emotional empathy served as the dependent variables.

Follower task. The follower task was designed to investigate whether produced synchrony increased when interacting with a human partner compared to a computer. In this task, the partners led the interaction by sending light signals in slow or fast tempo. Participants were told falsely that their partner was either human or the computer, where in fact their partner was always a computer. The participants' task was to respond to every light signal by sending exactly one signal back. Note that participants were never asked to synchronize their signals in the task. The experimental design when the participant was the follower was an animacy (partner is human or a computer) x speed (fast or slow) x group (ASD or NT) mixed-model factorial design. Synchroization served as a dependent variable, where synchronization was operationalized as standard deviations of the time interval between the partner’s and the subject's signals.

Procedure. At the beginning of each interaction phase, the computer assigned the participant to the leader or the follower role and introduced the partner by displaying her avatar. All partner avatars could be distinguished by their color and a nickname written inside the avatar, both of which were randomized across participants.

In leader rounds, in which participants were asked to send beats at a designated rate, a smaller “tutor circle” visualized the tempo for the next interaction round (fast or slow). The tutor circle sent 4 light signals after which the participant was asked to send light signals in the same tempo by pressing the space bar. There was one practice round at the beginning of the experiment, during which the participant practiced sending signals in a given tempo without a partner. Each round lasted 20 signals in the fast and 13 signals in the slow condition to keep the lengths of rounds equal across speed conditions. At the end of each interaction phase the participant was asked to rate his empathy towards the current partner by moving a slider across a continuous scale. Starting in the middle, the slider could be moved to the left (not at all) and to the right (fully). This continuous rating was transformed into ratings ranging from -10 to +10.

In follower rounds, a fixation cross indicated the start of each round followed by the first light signal from the partner. Participants were instructed to answer each signal by sending back exactly one signal.

Each participant completed 12 rounds in the role of the leader, blocked in 4 interaction phases of 3 rounds each, and 16 rounds in the role of the follower blocked in 4 interaction phases of 4 rounds each. Each participant started in the role of the leader and roles alternated after every second interaction phase. Within an interaction phase, partner characteristics were held constant (i.e., synchronous vs. asynchronous in the leader task, and human vs. computer in the follower task). The order of partner characteristics was randomized across participants. Within each interaction phase slow and fast rounds were pseudo-randomized.

Manipulations

Leader task. In the leader task, the phase lag between a participant's movement and the putative movement of a partner was set to 50% of the nominal inter-beat interval (IBI), so that the computer-generated beat followed the participant's beat by 500 ms (fast condition) and 750 ms (slow condition) respectively, resulting in anti-phase synchrony. Based on observations from a pilot study, in order to model a human interaction partner, we simulated phase lags at the beginning of a round to be shorter than half the nominal lag in slow rounds and longer in the fast rounds. Thus, the response time of the simulated partner was set to 10% below or 10% above half the nominal IBI in slow and fast rounds, respectively, and increased or decreased linearly to half the IBI at the end of the round. We used uniform noise around this lag to manipulate whether the partner sent his beats in a synchronous or asynchronous manner. In the synchronous condition, no noise was added to the phase lag. In the asynchronous condition, uniform noise was added (100% of the phase lag). At the end of the experiment, participants were asked to indicate how much they perceived that their interaction partners had temporally adapted their signals with theirs on a continuous scale ranging from "not at all" to "very much”.

Follower task. In the follower task, virtual partners led the communication by sending one beat every 1 sec (fast) or every 1.5 sec (slow). To increase plausibility of playing with a human partner, the IBIs were set to 15% below or 15% above the nominal IBI in slow and fast rounds, respectively, and increased or decreased linearly to the nominal IBI at the end of the round. In addition, uniform noise was added (ranging from 5% at the beginning to 1% at the end of the run). Notably, the same algorithm was used to simulate the partner in "human" and "computer" conditions. Thus, the manipulation of animacy only consisted in the instructions, and great effort was made to strengthen the cover story. We invited two participants at a time, seated them in front of computers in the same room and had them start the experiment simultaneously. Two other participants were supposedly seated in the next room and the experimenter left the room before the start of the experiment pretending to check whether they were ready to go by talking loudly to herself. Participants were asked to choose nicknames and saw the nicknames of their partners on screen during the interaction. At the beginning half of the follower rounds, a message was prompted on the screen asking to wait for their partner to be ready. After each follower round, participants were asked to wait while their partner answered the empathy questions. To check whether the manipulation was successful, participants rated how much they were under the impression that the partners had been simulated by the computer on a Likert scale ranging from 1 (not at all) to 5 (absolutely), at the very end of the task.

3.3.3.3 Individual Difference Measures of Empathy

To relate produced synchronization behavior to individual empathy functions, we implemented two measures that have been proven sensitive in detecting social-cognitive deficits in individuals with ASD.

Movie for the Assessment of Social Cognition. The Movie for the Assessment of Social Cognition (MASC) was developed for the ecologically valid assessment of mindreading abilities in adults (Dziobek et al., 2006). Participants watch a short film showing four persons spending an evening together with the instruction to try to understand the mental states of the characters and to answer 45 multiple choice questions at given breaks (e.g., “What is Cliff thinking?”, “Why is Michael doing this?”). The questions are based on traditional ToM concepts such as first and second order false belief, deception, faux pas, persuasion, metaphor, sarcasm, or irony. Each correct response is scored as one point and responses are added together to form a total score. The MASC was validated in a sample of patients diagnosed with ASD (Dziobek et al., 2006) and showed the highest discriminative power in detecting ToM deficits compared to standard social-cognitive tasks, like the Strange Stories Task (Happé, 1994), and a basic emotion recognition paradigm (Ekman & Friesen, 1971).

Reading the Mind in the Eyes task. The revised version of the “Reading the Mind in the Eyes” task (RME; Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001) involves inferring the mental state of a person solely from information conveyed by photographs of that person’s eyes. For each of the 40 pairs of eyes, participants were asked to pick one out of four varying mental state descriptors (e.g., interested, hostile). The test is scored by adding up the number of mental state attributions correctly identified. Since the MASC and the RME were administered in a separate session, scores from one NT participant, who dropped out of the study, are missing.

3.3.3.4 Statistical Computations

The 3 items for emotional empathy in the leader task showed high internal consistency for synchronous and asynchronous rounds (Cronbach’s αs > .81), so that responses for all 3 questions were averaged to yield a measure of emotional empathy. Following the suggestions made by (Cumming, 2014) and endorsed by Psychological Science we report effect sizes and 95% confidence intervals (CI) for all crucial comparisons. For effects found in analyses of variance, we report the 95% CIs for the effect sizes of main and interaction effects.

3.3.4 RESULTS

3.3.4.1 Leader Task - Effects of Perceived Synchronization on Empathy

Cognitive empathy. The cognitive empathy score was subjected to a 2 (synchrony) x 2 (group) ANOVA. A significant main effect of synchrony showed that participants generally reported higher cognitive empathy with the partner in the synchronous (M = 0.17, SE = 0.64) than the asynchronous condition (M = -1.7, SE = 0.71, $F(1,40) = 6.97$, $p = .01$, $\eta_p^2 = .15$, 95% CI [.008; .342], Figure 1). The ASD group reported generally less cognitive empathy than the NT control group as shown by a significant main effect of the factor group (ASD: M = -2.79, SE = 0.86, NT: M = 1.26, SE = 0.82, $F(1,40) = 11.58$, $p = .002$, $\eta_p^2 = .22$, 95% CI[.038; .416]). Most importantly, only the NT group showed significantly more cognitive empathy towards the synchronous partner than the asynchronous partner as revealed by the significant interaction effect of synchrony and group ($F(1,40) = 6.74$, $p = .01$, $\eta_p^2 =$

0.14, 95% CI [.006; .337]) and confirmed in planned post hoc contrasts (ASD: M_{synch}= -2.78, SE = 0.93, M_{asynch} = -2.81, SE = 1.08, p =.96, Cohen's d = 0; NT: M_{synch} = 3.11, SE = 0.88, M_{asynch} = -0.59, SE = 1.03, p = .007, Cohen's d = 0.8).

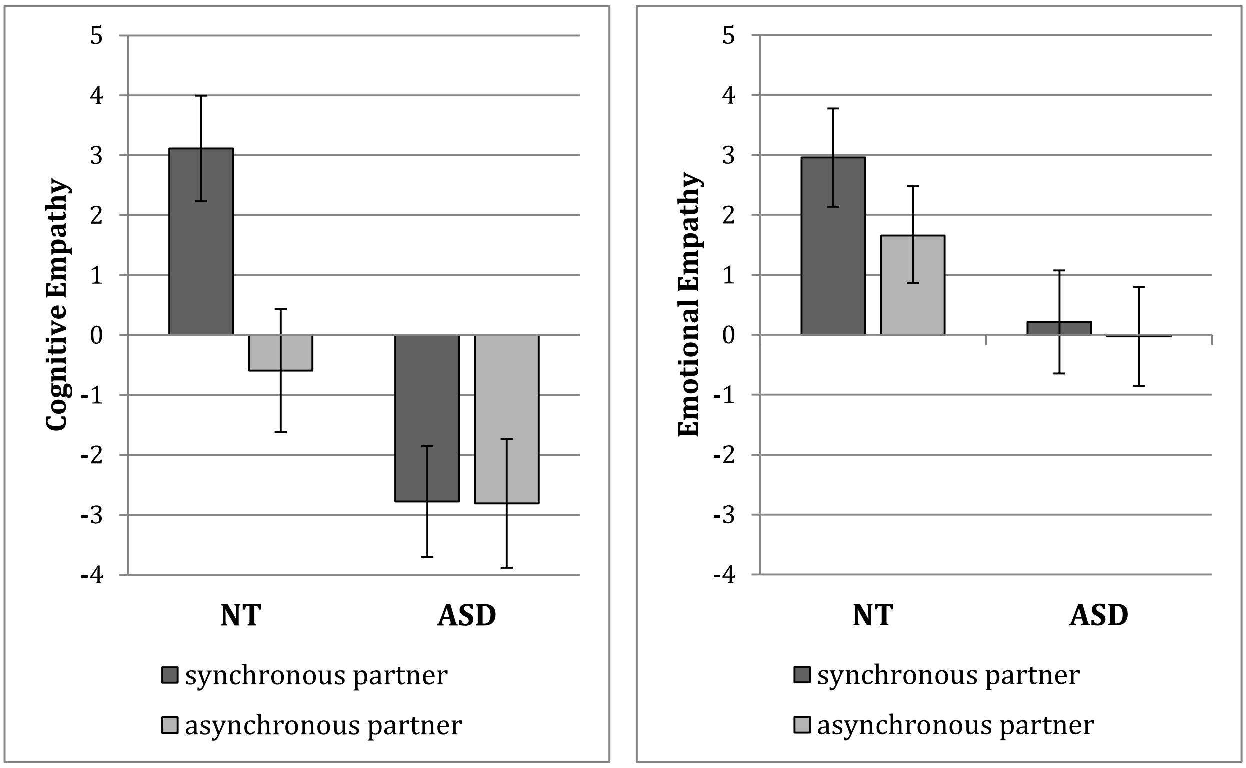

Figure 9. Results for cognitive empathy ratings (left panel) and emotional empathy ratings (right panel) following synchronous and asynchronous interaction.
Abbreviations: NT, neurotypical control group, ASD, autism spectrum disorder group

Emotional empathy. An ANOVA on the compound measure of emotional empathy revealed a significant main effect of synchrony indicating that participants felt that they shared their feelings more with the synchronous (M =1.58, SE = 0.6) than the asynchronous partner (M = 0.81, SE = 0.57, F(1,40) = 5.94, p = .02, η_p^2 = 0.13, 95% CI[0.002; 0.321], Figure 9). The group difference was marginally significant, indicating that across synchrony conditions people with ASD tended to report less empathy compared to the NT group (ASD: M = 0.09, SE = 0.81, NT: M = 2.31, SE = 0.77, F(1,40) = 3.9, p = .06, η_p^2 = 0.09, 95% CI [0; 0.273]). There was a trend towards an interaction effect of synchrony and group (F(1,40) = 2.8, p = .1, η_p^2 = 0.07, 95% CI[0; 0.242]), indicating that analog to cognitive empathy, the NT group showed more emotional empathy towards the synchronous (M = 2.96, SE = 0.82) than the asynchronous partner (M = 1.65, SE = 0.79), while the ASD group did not differentiate as much between partners (M_{synch}= 0.21, SE = 0.86, M_{asynch} = -0.03, SE = 0.82). Post hoc analyses supported this trend showing a significant difference in NT ($p = .01$, Cohen's $d = 0.39$) but not ASD group ($p = .55$, Cohen's $d = 0.26$).

Control analyses. In order to rule out alternative explanations for the interaction effect of group and synchrony, additional control analyses were performed.

Task performance. One alternative explanation could be that the ability to follow instructions (i.e., sending light signals at a certain designated tempo) differed between groups or was differentialy affected by the partner's synchrony or asynchrony in ASD participants compared to NT individuals. Impaired performance in following instructions might in turn affect subjective impressions of empathy towards the partner. To determine whether task performance was different between groups the average intervals between two light signals of a subject was analyzed and fed into an ANOVA with the factors synchrony of the partner (synchronous vs. asynchronous), speed (fast vs. slow) and group (ASD vs. NT). Neither the factor group ($p = .44$) nor any interactions with the factor group were significant (all $p > .32$). Therefore we assume that both groups were equally able to keep a steady pace at the predetermined tempo.

Perceived synchrony. Another alternative explanation might be that subjective impressions of synchrony differed between groups. To determine whether the synchrony manipulation was perceived similarly in both groups, subjective post experimental ratings of synchrony were subjected to a 2 (synchrony) x 2 (group) analysis of variance. The continuous ratings were transformed into ratings ranging from -10 to +10. Results showed that the synchronous condition produced higher perceptions of synchrony ($M = 6.69$, $SE = 0.58$) than did the asynchrony condition ($M = 0.8$, $SE = 0.78$, $F(1,40) = 39.67$, $p < .001$, $\eta_p^2 = .50$). Notably, both groups perceived differences in synchrony to a comparable extent as shown by the non-significant interaction effect, $F(1,40) = 0.58$, $p = .45$, $\eta_p^2 = 0.01$.

3.3.4.2 Follower Task - Produced Synchronization

Animacy manipulation. During written debriefing, both groups scored equally low on a Likert Scale ranging from 1 (not at all) to 5 (absolutely) when asked at the end of the experiment if they felt that all partners had been simulated by the computer (NT: $M = 2.18$, ASD: $M = 1.5$, $p = .13$).

Group comparisons. Synchronization in the follower task was subjected to a 2 (animacy) x 2 (speed) x 2 (group) analysis of variance (ANOVA). One NT subject exceeded the group mean by 3 SD in all conditions and was excluded from the analyses. Although descriptively results hinted at higher synchronization (i.e., smaller asynchronies) with a human partner than a computer across participants (human: $M = 106.17$ ms, $SE = 8.19$ computer: $M = 117.49$ ms, $SE = 11.11$), this main effect of animacy did not reach statistical significance, ($F(1,39) = 2.13$, $p = .15$, $\eta_p^2 = .05$, 95% CI [0; .22]). The effect of group ($F(1,39) = 0.98$, $p = .33$, $\eta_p^2 = 0.03$, 95% CI [0; 0.18]) and the interaction of group and animacy ($F(1,39) = 0.08$, $p = .78$, $\eta_p^2 = 0.002$, 95% CI [0; 0.08]) were not significant.

Associations between produced synchronization and individual differences in objective measures of cognitive empathy. In the ASD group lower asynchronies were associated with better cognitive empathy as measured by the MASC during interaction with human partners (fast: r = -.61, p = .004, 95% CI [-.83; -.23]; slow: r = -.58, p = .008, 95% CI [-.81; -.18]), while the same relationship during interacting with the computer was not significant (fast: r = -.41, p = .07, 95% CI [-0.72; 0.04], slow: r = -.35, p =.14, 95% CI [-.69; .11]). Within the ASD group, direct comparisons between correlations (following the approach set forth by Steiger, 1980) in the human and the computer condition were marginally significant (fast: p = .05, slow: p = .08). In the NT group, asynchronies were not related to mentalizing abilities (human; fast: r = .13, p = .61, slow: r = -.05, p = .85; computer; fast: r = -.07, p = .79, slow: r = .03, p = .91). Comparisons of correlations between groups (Cohen, J., Cohen, P., West, S. G., & Aiken, 2003) were marginally significant or significant (fast: p = .01, slow: p = .07). A similar pattern of results was found when using the RME to measure cognitive empathy functions. RME data was lost from 4 ASD participants due to technical problems, leaving a sample size of n = 16. Again, the relationship between asynchronies in the ASD group were significant during interaction with human partners (fast: r = -.67, p = .004, 95% CI [-.87; -.26], slow: r = -.69, p = .003, 95% CI [-.88; -.29]), but not when interacting with a computer (fast: r = -.46, p = .07, 95% CI [-.78; .05], slow: r = -.42, p = .10, 95% CI [-.76; .01]). Direct comparisons of correlations in the human and the computer condition were marginally significant (fast: p = .05, slow: p = .07). In the NT group, synchronization and mentalizing were unrelated (human; fast: r = .20, p = .39, slow: r = .002, p = .99, computer; fast: r = -.14, p = .56, slow: r = .09, p = .70). Comparisons of correlations between groups were significant (fast: p = .003, slow: p = .01).

3.3.5 DISCUSSION

The goal of the current study was to investigate the effect of perceived interpersonal synchrony during a simple interactive tapping task adapted from Cacioppo and colleagues (2014) on cognitive and emotional empathy in individuals with and without autism. To this end, participants were asked to take the role of the leader in a beat-based communication task, while their virtual partners were programed to follow in a synchronous or asynchronous way. Analyses showed that the NT control group, but not the ASD group, reported more cognitive empathy towards their partner if the partner had followed them in a synchronous compared to an asynchronous way.

We also investigated the effect of animacy (interacting with an ostensible human player or the computer) on produced synchronization in those interactions, in which the participant follows in the interaction (follower task). In contrast to our hypothesis, we could not show higher synchronization when participants interacted with an ostensible human partner compared to the computer. We furthermore did not observe differences in synchronization between ASD and NT participants. Interestingly though, within the ASD group, the degree of synchronization with the ostensible human partner was correlated with cognitive empathy as measured with two objective cognitive empathy tasks, the MASC and the RME. Indeed, we found that higher synchrony during the interaction was related to higher cognitive empathy.

We found that in non-autistic individuals perceiving a partner as interacting more synchronously leads to higher cognitive empathy towards this partner. This is in line with previous research showing positive social consequences of synchronous behavior such as increased rapport, affiliation, pro-social behavior, and cooperation (Bernieri, 1988; Cacioppo et al., 2014; Hove & Risen, 2009; Kirschner & Tomasello, 2010; Valdesolo et al., 2010; Wiltermuth & Heath, 2009; Chartrand & Lakin, 2013). Our study adds to this line of research by showing that a follower's synchronization during interaction increases the leader's subjective estimate of how much he is able to understand the thoughts and intentions of the other. Given these results, we may also speculate about the mechanism underlying the link between behavioral synchrony and cognitive empathy. More specifically, it has been shown that interpersonal synchronization recruits brain areas that have previously been associated with social cognition in general and cognitive and emotional empathy in particular, including midline structures such as ventromedial prefrontal cortex and the action observation system located in inferior parietal lobule (Cacioppo et al., 2014; Fairhurst, Janata, & Keller, 2013). The temporal dynamics of brain activations during coordinated action (e.g., a dyad playing the guitar) have been investigated further in hyperscanning-EEG studies, suggesting that interbrain oscillatory coupling at electrodesides that are consistent with these brain areas may play a role in guiding interpersonal movement coordination (Lindenberger, Li, Gruber, & Müller, 2009; Yun, Watanabe, & Shimojo, 2012). These results are in line with simulation theories arguing that observed movements of another person are mirrored on the behavioral as well as the neural level and thus allow us to share and understand thoughts and feelings of others (Gallese, 2003). However, the role of inter-brain synchrony in mediating the effect of behavioral synchrony and higher-order social functions awaits further exploration.

In contrast to the NT group, perceived synchronous interaction did not increase cognitive empathy in ASD. Given that participants with ASD did subjectively perceive the difference in synchronization between their partners, this might indicate that synchronization does not mediate cognitive empathy in ASD to the same degree as in controls. Impairments in the link between perceived synchrony and cognitive empathy might contribute more generally to the social deficits of individuals with ASD.

When focusing on the participant’s produced synchronization during the follower task, we did not observe a difference in the tendency to synchronize when interacting with an ostensible human partner compared to the computer, although the results descriptively pointed in this expected direction, i.e., participants tended to synchronize more when they thought that their partner was a human being vs. a computer. One reason for the non-significant result might be that the manipulation of human vs. computer was too subtle. Previous studies have shown that humans have strong tendencies to attribute mental states to moving geometric shapes (Heider & Simmel, 1944), and in the current study, both human and computer players were represented by the same circle-shaped signals. In addition, it has been shown that individuals only make a difference between the interaction with a human and a computer if they are motivated to cooperate (McCabe, Houser, Ryan, Smith, & Trouard, 2001). Since our study did not provide an incentive to cooperate, this might be an alternative explanation of why synchronization behavior did not differ between conditions.

The potential weakness of our animacy manipulation might explain why in contrast to previous studies (Fitzpatrick et al., 2013; Marsh et al., 2013) we did not find group differences and a group x condition interaction effect on produced synchrony. Using a rocking chair paradigm, Marsh et al. (2013) showed that children with ASD synchronize their movements less to a parent than typically developing children. In contrast to those previous studies, our synchronization paradigm excluded any naturalistic social information during the interaction such as body language and verbal interactions (e.g., parents in the study by Marsh et al. (2013) read a book to their child while sitting side-by-side) which might explain our divergent results in this study. Possibly individuals with ASD are able to synchronize their movements when social-cognitive load is low as in the current paradigm, but fail to synchronize in more complex real life interaction.

Interestingly, we did find a significant correlation in the ASD group between produced synchrony and cognitive empathy performance as measured with the MASC (Dziobek et al., 2006) and the RME (Baron-Cohen et al., 2001), indicating that higher produced synchronization is associated with higher cognitive empathy performance in individuals with ASD. This speaks against the complete absence of a mechanism linking synchronization functions to cognitive empathy. However, correlations of synchrony and cognitive empathy when interacting with a putative human partner were only marginally larger than when interacting with the computer. This raises the question if synchronization, as it was measured in this study, is truly a social function. A possibility for future research could be to investigate whether social cognition is related to interpersonal synchronization specifically or sensorimotor synchronization abilities more generally. The fact that we were not able to observe significant correlations in the NT group might be attributed to the much lower variance in MASC scores in the NT group compared to the ASD group.

Taken together our results confirm previous studies in non-autistic individuals showing associations between interpersonal synchronization and social functions, extending the literature specifically to cognitive empathy. With respect to autistic individuals, we found that in a task with low social demands the ability to perceive synchronization in others and the tendency to produce synchronized behavior seem to be widely intact. Although being followed by a synchronous partner compared to an asynchronous partner did not result in higher cognitive empathy ratings towards that partner in the ASD group, produced synchronization behavior was related to cognitive empathy performance as measured with an external objective task. This suggests that the mechanism linking synchronization with cognitive empathy might be attenuated, yet not absent in ASD. It seems possible that the translation of an interaction partner’s synchrony into an understanding of his mental states demands more time in ASD than in controls and is aided by more naturalistic social cue displays, both of which our minimal social synchonization paradigm did not allow for. This might be relevant for interventions, where the trainng of interpersonal synchronization might have a positive effect on empathy and social behavior. Indeed, recent training studies found dance/movement interventions targeting synchronization and imitation to increase social skills in adults with ASD (Koch, Mehl, Sobanski, Sieber, & Fuchs, 2014; Koehne, Behrends, Fairhurst, & Dziobek, 2015).

One main limitation of our study is that it lacks ecological validity, given that it relies on reduced social communication signals. While we deem this kind of well-controlled experiment necessary to establish causal relationships between synchrony and empathy, we would suggest that future studies should explore this mechanism in more naturalistic settings. In addition, participants in the leader task were probed for cognitive and emotional empathy after each interaction with a partner, so that effects of partner synchrony on cognitive empathy might at least partly be due to task demands. In contrast to previous studies (Cacioppo et al., 2014) we refrained from probing for perceived synchrony after each interaction in order to minimize task demands. However, future studies should additionally embed empathy items in longer item lists to corroborate these findings while disguising the aim of the study.

3.3.6 CONCLUSION

We found perceived interpersonal synchrony during a simple communicative finger tapping task to subjectively enhanced cognitive empathy towards the interaction partner in neurotypical participants, but not in individuals with ASD. In ASD, however, the degree of produced synchronization during communication with an ostensible human partner was correlated with cognitive empathy performance measured in external objective tasks. We conclude that synchrony during social interactions is related to cognitive empathy in non-autistic individuals and that this mechanism might be attenuated, yet not absent, in individuals with ASD. Further exploration of this mechanism is warranted towards the exploration of factors mitigating social deficits of individuals with ASD.

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1.1 STUDY 6: EVALUATION OF AN IMITATION AND SYNCHRONIZATION-BASED DANCE/MOVEMENT INTERVENTION TO FOSTER EMPATHY IN ADULTS WITH AUTISM SPECTRUM DISORDER[6]

1.1.1 ABSTRACT

Background: Since social cognition is impaired in individuals with autism spectrum disorder (ASD), this study aimed at establishing the efficacy of a newly developed imitation and synchronization based dance/movement intervention in fostering emotion inference and empathic feelings (i.e., emotional reaction to feelings of others) in adults with high-functioning ASD.

Methods: Fifty-five adults with ASD (IQ ≥ 85), which were blind to the aim of the study were assigned to either receive ten weeks of a dance/movement intervention focusing on interpersonal movement imitation and synchronization (SI-DMI, N = 27) or a control movement intervention (CMI, N = 24) focusing on individual motor coordination. Primary outcome measure was the objective Mulifaceted Empathy Test targeting emotion inference and empathic feelings. Secondary outcomes were scores on the self-rated Interpersonal Reactivity Index. The well-established automatic imitation task and synchronization finger tapping task were used to quantify effects on imitation and synchronization functions, complemented by the more naturalistic Assessment of Spontaneous Interaction in Movement.

Results: Intention-to-treat analyses revealed that from baseline to three months, patients treated with SI-DMI showed significantly larger improvement in emotion inference (d = 0.58) but not empathic feelings than those treated with CMI (d = -0.04). On the close generalization level, SI-DMI compared to CMI increased synchronization skills and imitation tendencies as well as whole-body imitation/synchronization and movement reciprocity/dialogue.

Conclusions: A synchronization and imitation-based dance/movement intervention can be successful in promoting emotion inference in adults with ASD and warrants further investigation.

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3.4.2 INTRODUCTION

Autism spectrum disorder (ASD) is characterized by impaired social interaction and communication, and a restricted repertoire of activities and interests (American Psychiatric Association, 2013). Deficits in social cognition, e.g. inferring others' mental states such as emotions and perspective taking are at the core of the disorder (Baron-Cohen, 2001; Harms, Martin, & Wallace, 2010; Schwenck et al., 2012). Socio-emotional functions such as empathic feelings (i.e., being emotionally affected by someone else's emotions) have also been suggested to be aberrant, though less consistently (Bird et al., 2010; Hadjikhani et al., 2014; Minio-Paluello, Baron-Cohen, Avenanti, Walsh, & Aglioti, 2009; Rogers, Dziobek, Hassenstab, Wolf, & Convit, 2007) Rigorously tested treatment options for adults with ASD targeting social cognition deficits, however, are scarce as shown by the fact that only 3 randomized controlled trials were undertaken, with very small sample sizes (Bishop-Fitzpatrick, Minshew, & Eack, 2013). Of note, those interventions target compensatory mechanisms focusing on explicit top down learning strategies. Although individuals with ASD have been shown to profit from explicit strategies, they are likely demanding cognitive resources and thus add strain in real life social situations (Glaser, 1990). Consequently it may alternatively be promising to develop interventions for social cognition that are implicit in nature.

In social interaction humans show spontaneous coordination of movements, i.e., imitation of facial expressions and postures, and movement synchronization, such as falling into lock-step when walking side by side (for a review cf. Chartrand & Lakin, 2013). Interestingly, both imitation and synchronization have been reported aberrant in autism (Edwards, 2014; Marsh et al., 2013; Vanvuchelen, Roeyers, & De Weerdt, 2011) and it has been suggested that those dysfunctions contribute to social cognition deficits (Kana, Wadsworth, & Travers, 2010; Perkins, Stokes, McGillivray, & Bittar, 2010). For instance, Marsh et al. (2013) showed that children with ASD tend to synchronize their rocking-chair movements less to those of their parents compared to typically developing children. Here we suggest that interpersonal movement synchronization and imitation might be a target for social-cognitive interventions in ASD.

Our rationale is backed up by extensive basic research linking imitation and synchronization to social cognition (Behrends, Müller, & Dziobek, 2012). It was shown that synchronizing movements with those of another person during an interaction is associated with greater rapport, feelings of closeness and pro-social behavior (Bernieri, 1988; Cacioppo et al., 2014; Catmur & Heyes, 2013; Hove & Risen, 2009; Kirschner & Tomasello, 2010; Wiltermuth & Heath, 2009). Similarly, imitation of postures, facial expressions, and other behaviors entail positive social consequences including liking, emotion recognition, generosity, and reduced racial prejudice (e.g., Bate, Cook, Mole, & Cole, 2013; Dimberg, Thunberg, & Elmehed, 2000; Stel & van Knippenberg, 2008; van Baaren, Holland, Steenaert, & van Knippenberg, 2003). In addition, modulation of spontaneous imitation through top-down control (imitation inhibition) has been suggested to play a crucial role in perspective taking

(Brass, Ruby, & Spengler, 2009; Santiesteban, Banissy, Catmur, & Bird, 2012; Santiesteban, White, et al., 2012).

Interestingly, the idea of using imitation and synchronization in clinical interventions to target social functions has a long tradition in dance/movement therapy in general and in working with children with autism in particular (Adler, 1970; Archambeau & Szymanski, 1977; Samaritter & Payne, 2013; Scharoun, Reinders, Bryden, & Fletcher, 2014). Dance/movement therapists apply empathic reflection of their client's movements (i.e., mirroring of the movement quality and/or its form) to build a relationship and enhance emotional understanding between the therapist and the client (Sandel, 1952). A recent 7-week intervention study focusing on mirroring in movement showed improved self-reported social skills in young adults with autism (Koch, Mehl, Sobanski, Sieber, & Fuchs, 2014), providing some empirical evidence for this notion.

Taken together, fostering interpersonal movement imitation and synchronization might serve as an effective leverage to enhance social cognition in adults with ASD, but experimental evidence of its efficacy is lacking. In the context of this study we developed an imitation and synchronization-based dance/movement intervention (SI-DMI) for adults with ASD aiming at fostering social cognition. We aim at showing that SI-DMI compared to a control movement intervention (CMI) enhances socio-cognitive (i.e., emotion inference and perspective taking) and socio-affective processes (i.e., empathic feelings) in adults with ASD.

3.4.3 METHODS

This participant-blind, controlled parallel-group trial took place at the Psychology department of Freie Universität Berlin, Germany, from 12/2011 to 03/2013 and was approved by the ethics committee of the German Psychological Society (DGPs).

3.4.3.1 Participants

Eligible participants (N = 55) were aged 18 through 55 years with a diagnosis of high-functioning ASD, average intelligence (IQ > 85), right-handedness without severe physical conditions, and not currently undergoing psychotherapy. ASD participants were recruited through the autism outpatient clinic of the Charité University Medicine Berlin or referred to us by specialized clinicians and centers, and were diagnosed according to DSM-IV/ICD-10 criteria for Asperger disorder and autistic disorder using the Autism Diagnostic Observation Schedule (ADOS) (Lord, Rutter, DiLavore, & Risi, 2002) and the Autism Diagnostic Interview – Revised (ADI-R) (Lord, Rutter, & Le Couteur, 1994) if parental informants were available. Participants gave written informed consent.

3.4.3.2 Interventions

SI-DMI and CMI were administered in ten 90 min sessions over the course of three months in small groups of 4-10 members (group size varied based on participant's availability and due to dropouts). Participants were blind to the goal of the study and fully debriefed in writing at the end. To provide a rationale for participating in the intervention, both SI-DMI and CMI were announced as movement programs for adults with ASD to promote motor functions and general physical wellbeing (cf Figure 10 for an illustration of both interventions.).

Figure 10. Illustration of interventions in study 6**.** The imitation and synchronization- based dance/movement intervention (SI-DMI, left panel) focused on imitation and synchronization while the control movement intervention (CMI, right panel) focused on individual motor coordination and fitness. The picture was blurred for participant's anonymity. All participants gave written consent to the publication of their pictures.

SI-DMI was developed and manualized jointly by a child and adolescent psychiatrist with dance movement therapy (DMT) education (A.B.) and a professional dancer/choreographer. Compared to integrative DMT, SI-DMI realized a more focused and standardized approach, that has been theoretically outlined in further detail elsewhere (Behrends et al., 2012). Each session of SI-DMI followed the same structure (cf Table 9). The primary components (70%) were exercises for dyads, small groups, and the entire group focusing on interpersonal movement imitation and synchronization with and without music. For instance, in mirroring tasks participants imitated a repetitive movement initiated by another participant (such as arm swings) until synchrony occurred. In circle dances, participants learned choreographed movement sequences through imitation over the course of several sessions and then performed the dance in synchrony. Movement complexity and improvisation of movement gradually increased over the course of the intervention. Since top-down modulation of the spontaneous tendency to imitate (imitation inhibition) has been shown to affect perspective-taking (Brass et al., 2009; Santiesteban, Banissy, et al., 2012; Santiesteban, White, et al., 2012), exact imitation/synchronization tasks were alternated with tasks focusing on variation and turn-taking in joint movement in every session. For example, during a mirroring task, participants were asked to vary the size and speed of a movement that they had previously imitated. The most advanced form of variation and turn-taking was a face-to-face movement dialogue in which participants built on each other's movements to create interaction in movement. In order to strengthen the perception of the own body and individual movement expression as basic requirements for reciprocity in movement (Behrends et al., 2012), respective tasks were also integrated in every session (approx. 30%). Homework such as observing and imitating movements in others was assigned to facilitate the transfer of movement observation and imitation into every-day life interactions. Structure and contents of the sessions were specifically adapted to the needs of individuals with autism, which entailed among others predictable session structure, avoidance of sensory overload (e.g., interpersonal connection through ropes instead of direct touch), and possibility for time out.

Table 9. Session structure of SI-DMI

Function	Format/setting	Content
1. Brief verbal exchange and discussion of homework	Sitting circle	Opportunity to express needs and share state of mind, feedback on homework
2. Warm-up	Joint movement ritual	Movement sequence of increasing complexity
3. Movement expression and perception	Individual and interactive tasks	Variations of everyday movements like walking, movement observation, gradual introduction of different creative elements such as variations in expression and contrasting of a given movement
4. Main part	Interactive imitation and synchronization tasks in dyads, small groups, and the entire group	Imitative and mirroring tasks with variations and contrasting elements in different positioning in two forms: a) improvised movement (of increasing complexity and variation), and b) specified choreography (e.g. simple circle dances are learned and realized by participants over subsequent lessons)
5. Cool-down	Quiet self-perception tasks	Relaxation, self-focusing / awareness
6. Brief final verbal exchange and assignment of homework	Sitting circle	Feedback and opportunity to share movement experience; homework assignment

Although CMI was also administered in a group setting, it did not involve tasks on interpersonal movement imitation and synchronization, but individual tasks on dexterity, balance, and endurance (e.g. juggling, simple yoga poses, or practicing on exercise machines) that were offered in a circle training-like format. All tasks were offered in 3-4 difficulty levels and participants monitored their progress in diaries to enhance motivation. While each task was introduced and shown briefly at the beginning of each session, detailed instructions were provided in writing to avoid learning through imitation. In addition, no two participants performed the same task at the same time and all faced the wall to minimize observation of movements while performing an exercise. Physical effort and structural aspects such as group setting, session structure, use of music, verbal exchange, and homework were kept constant across interventions.

3.4.3.3 Outcome Measures

On a close generalization level we expected SI-DMI to enhance imitation and synchronization, which would on a distant generalization level transfer into improved emotion inference and empathic feelings. Thus, the Multifaceted Empathy Test (MET) (Dziobek et al., 2008) was our primary outcome and the Interpersonal Reactivity Index (IRI) (Davis, 1983) together with imitation/synchronization paradigms and the more naturalistic Assessment of Spontaneous Interaction in Movement (ASIM) our secondary outcome measures that were assessed at baseline and within 4 weeks after the intervention.

Primary Outcome Measure. The Multifaceted Empathy Test (MET) (Dziobek et al., 2008) is an ecologically valid measure that allows for the simultaneous assessment of emotion inference and empathic feelings, and has been proven sensitive in ASD. The computer-based MET consists of 40 photographs depicting people in emotionally charged situations. To assess emotion inference, subjects are required to infer the emotions of the individuals shown in the photographs by selecting one of four mental state descriptors. To assess empathic feelings, subjects rate how much they share the feelings of the individuals displayed in the pictures on a 9-point Likert scale. The MET has been shown to be a reliable measure of emotion inference (Cronbach's alpha = 0.71) and empathic feelings (alpha = 0.91) (Dziobek et al., 2008).

Secondary Outcome Measures

Interpersonal Reactivity Index (IRI). Individual differences in self-rated Perspective Taking (PT) and Empathic Concern (EC) on the trait level were assessed using the IRI (Davis, 1983). The PT scale assesses the tendency to spontaneously adopt the psychological point of view of others (e.g., I try to understand my friends better by imagining how things look from their perspective). The EC scale taps the respondents' feelings of warmth, compassion, and concern for others (e.g., I often have tender, concerned feelings for people less fortunate than me).

Automatic imitation. To measure imitation tendencies we used the automatic imitation paradigm that has been well-established in basic research (e.g., Cook & Bird, 2012). In summary, participants perform a cued finger-lifting task while seeing task-irrelevant videos of either 1) a hand simultaneously performing the same movement in a mirrored fashion, or 2) a static hand. Reaction time (RT) differences between conditions 1) and 2) were used as a proxy for automatic imitation, assuming that the tendency of automatic imitation leads to shorter RTs in the moving hand condition (cf appendix of this study in section 3.4.7 for a detailed description).

Interpersonal synchronization. A finger tapping task was used that has previously been developed to investigate dynamic human interactions as they occur during group music making and dance (Fairhurst, Janata, & Keller, 2013). Participants were asked to tap in synchrony with the tones of virtual drumming partners, who were programmed to be either humanlike (i.e., variably adaptive to the participant's performance) or mechanic like a metronome (non-adaptive, cf appendix of this study in section 3.4.7 and Figure 12 in the appendix). The standard deviation of asynchronies between taps and tones (SD asynchrony) served as measure for synchronization performance with higher values reflecting weaker performance.

Assessment of Spontaneous Interaction in Movement (ASIM): The ASIM is an observation coding schedule allowing for a systematic and standardized assessment of dyadic interactional whole body movements and forms part of a new standardized assessment of a person's individual and interactional movement profile which we developed specifically for this study because no other naturalistic assessment of spontaneous, interactional whole-body movement was available. The assessment is based on the film-based Movement Profile Analysis (Bräuninger & Züger, 2007), which was designed to describe movement quality in the course of dance/movement therapy. Participants were asked to engage in simple 1-1.5 min movement and dance tasks to music, e.g., walking, in a predefined space. Two tasks (expanding/contracting and swing movements) were then repeated while a confederate joined the movement space. There was no instruction to interact, allowing for *spontaneous* interaction in movement for the participant. The confederate followed a semi-standardized choreography, which included several non-verbal offers to interact with the participant (e.g. turning toward the participant). Video recordings of the interactive movement set were analyzed for four spontaneous interactive movement criteria 1) orientation of gaze and body towards confederate, 2) relation in spatial movement, 3) imitation/synchronization, and 4) reciprocity/dialogue in movement. The ASIM coding criteria comprise quantitative and qualitative movement aspects. All movement parameters were judged on a scale ranging from 0 (not shown) to 3 (clearly and frequently shown, flexible and socially modulated) with detailed descriptions for each score. An example for the coding scheme is given in Table 12 in the appendix of this study. Ratings for the four different interactional movement patterns reflect an average of the two interactive movement tasks. Ratings were done by A.B., who was not blind to group allocation. To evaluate the reliability of this measure, 4 baseline assessments (2 individuals from CMI group and 2 from SI-DMI) and 4 additional assessments from neurotypical individuals were picked at random and rated by a second trained rater who was blind to diagnoses as well as group allocation. Two-way mixed, consistency, single-measures intraclass correlations (ICC) were in the excellent range for spontaneous imitation/synchronization (ICC = .92), reciprocity/dialogue (ICC = .78), and relation in spatial movement (ICC = .85). The ICC was only fair for the gaze and body orientation criterion (ICC = .45). Overall, results indicate that raters had a high degree of agreement and suggest that the ASIM is a reliable measure of more qualitative aspects of spontaneous movement in interaction.

3.4.3.4 Group Allocation

Between 12/2011 and 03/2013 patients were invited to participate in a movement program, advertised to target general motor functions and wellbeing. All groups (SI-DMI groups and CMI groups) were offered at different times of the week and with varying start dates throughout the year. After a telephone screening targeting exclusion criteria, participants who were all blind to the purpose of the study, chose their group based on time preferences. Participants were allocated sequentially in order of their declaration of their preference and a group was closed after including 10 participants. Each participant was allocated prior to baseline testing and first personal contact to guarantee that allocation could not be influenced based on symptom severity, level of functioning or baseline results.

3.4.3.5 Statistical Methods

Sample size calculations were based on previous studies on the effect of experimental manipulations of imitation/synchronization on social cognition (Hove & Risen, 2009; Stel & van Knippenberg, 2008; Valdesolo, Ouyang, & DeSteno, 2010; Wiltermuth & Heath, 2009) reporting medium to large effect sizes (d = .36 - 1.07). Thus, for our pre-post design, we proposed a conservative medium effect size of $\eta_p^2 = .13$ resulting in a total sample size of N = 56, given a significance level of 5% and power of 80%. Thus all N = 55 individuals evaluated as eligible were included into the study. Analyses were conducted on the modified intention-to-treat population with all participants analyzed in their assigned treatment condition. For participants who did not start (N = 2) or complete (N = 1) the intervention, data was imputed using the last observation carried forward. Alternative methods for handling missing data - namely complete case analysis and multiple imputations - yielded very similar results and levels of significance (cf. Table 13 and Table 14 in the appendix of this study). Outcome measures were analyzed using a repeated measure mixed model ANOVA with the inner subject factor time (pre and post intervention) and the between subject factor group (SI-DMI and CMI). Post hoc t-tests to further investigate interaction effects were Bonferroni corrected. Effect sizes for the interaction effects were calculated using η_p^2. For an estimation of clinical significance, Cohen's d was calculated for the treatment effect (difference between pre and post intervention) for both interventions separately. All analyzes were 2-tailed with a p-value-threshold of 5% and run using SPSS (version 20.0).

3.4.3.6 Missing Data

One subject from the CMI group was excluded from the automatic imitation analyses because he showed prolonged reaction times (> 3 SD from group mean) across all conditions at post intervention assessment. Only a subset of participants (SI-DMI: N = 16, CMI: N = 9) underwent ASIM due to restricted personal resources. All participants tested with the ASIM pre intervention were also tested after intervention and included in the analyses. All other missing data points are due to technical problems during data acquisition.

3.4.4 RESULTS

3.4.4.1 Recruitment

Between 12/2011 and 03/2013, 106 adults with high-functioning ASD were screened and those 55 evaluated as eligible were assigned to one of the two treatment conditions (cf. Figure 11). Four participants declined before baseline testing, 51 were included in ITT analyses. There were no significant between-group differences in terms of gender, age, intelligence (measured by a vocabulary test (Wortschatztest, WST) (Schmitz & Metzler, 1992), and symptom severity (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001, cf table 2). From those 51 participants included, additional parental information (ADI-R) was available for N = 16 participants. Most participants missed 0 sessions and only 2 participants (SI-DMI group) missed a 3rd session. Missed sessions were substituted by extra homework.

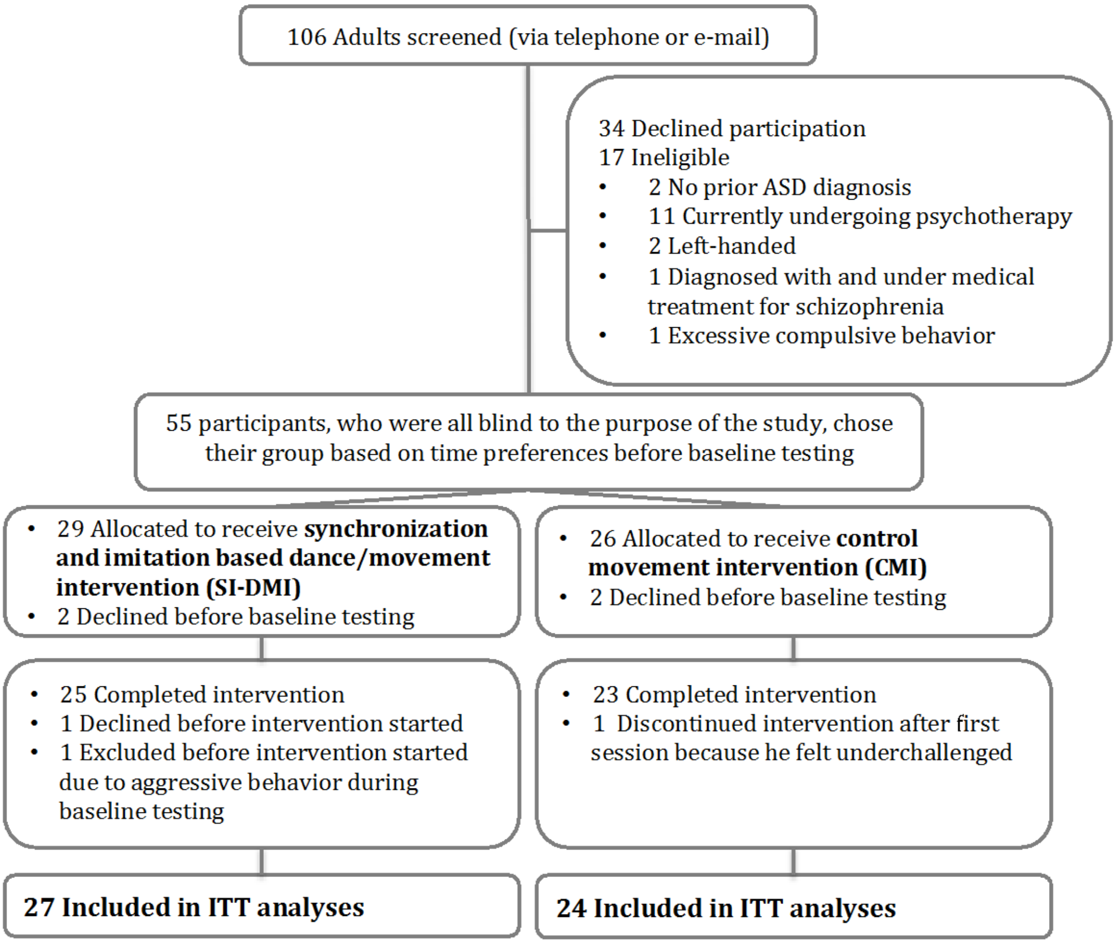

Figure 11. Flow of Patients Through the Trial.

Abbreviations: ASD: Autism Spectrum Disorders, SI-DMI: synchronization and imitation-based dance/movement intervention, CMI: control movement intervention, ITT: intention-to-treat.

Table 10. Baseline demographic and clinical characteristics.

Characteristic	SI-DMI[a] (N = 27)	CMI[a] (N = 24)	P Value[b]
Male sex	18	14	.54
Age	33.5 (9.1)	32.0 (9.1)	.54
In a relationship or married	3 (11.11)	3 (12.5)	.88
Finished high school[c] or vocational training	20 (74.07)	17 (70.83)	.80
Crystalline intelligence, IQ (WST)	106.7 (12.9)	109.8 (9.1)	.39
Symptom severity (ADOS)	10.3 (5.2)	10.6 (4.9)	.80
Autism Spectrum Quotient (AQ)	36.7 (7.3)	36.0 (10.2)	.79
Depressive symptoms (BDI-II)	16.4 (12.3)	14.0 (11.0)	.46
BSI Global severity index	0.91 (0.57)	0.81 (0.61)	.54
Received psychotherapy in the 6 months before baseline	5 (18.52)	5 (20.83)	.84
Behavioral therapy	3	1	
Psychoanalysis or psychodynamic therapy	1	2	
Other / not specified	1	2	

Abbreviations: SI-DMI, dance/movement intervention; CMI, control moment intervention; WST, Wortschatztest (German vocabulary test); ADOS, Autism Observation Schedule; AQ, Autism Quotient; BDI-II, Beck Depression Inventory (Beck, Steer, & Brown, 1996); BSI, Brief Symptom Inventory (Derogatis, 1993).

[a]Data are means (SD) or frequencies (%).

[b]P values for continuous variables were generated from independent sample t-tests; P values for categorical variables were generated from Pearson's χ^2 tests

[c] High School = German equivalent of High School Degree after 13 years of schooling.

3.4.4.2 Outcomes

Details of all ITT analyses are shown in Table 11. Improvements in emotion inference but not empathic feelings as measured with the MET were bigger in the SI-DMI group than in the CMI group ($p = .04$, $\eta_p^2 = .09$). Post hoc t-tests confirmed that emotion inference was significantly increased after SI-DMI ($p = .008$) but not after CMI ($p = .65$). Cohen's d for the difference between means at baseline and post treatment was $d = .58$ for the SI-DMI group compared to $d = -0.04$ for the CMI group, thus confirming clinical significance of the improvement in emotion inference (Samsa et al., 1999). There were no significant changes in self-ratings of trait-level perspective taking (IRI; $p = .68$) or empathic concern (IRI; $p = .71$).

On the close generalization level, a significant interaction effect of group x time revealed that the automatic imitation effect was increased in the SI-DMI group compared to the CMI group ($p = .04$, $\eta_p^2 = .08$) post intervention. Post hoc t-tests confirmed that automatic imitation was significantly increased after SI-DMI ($p = .02$, $d = 0.47$) but not after CMI ($p = .51$, $d = -0.03$). Similarly, asynchrony while interacting with human-like (i.e., variably adaptive) partners in the finger tapping task was reduced after SI-DMI compared to CMI ($p = .03$, $\eta_p^2 = 0.14$). Again, post hoc t-tests showed that asynchrony decreased significantly in the SI-DMI group ($p = .005$, $d = -0.63$) but not in the CMI group ($p = .68$, $d = 0.13$). Interestingly, asynchronies were unaffected by the interventions when interacting with a mechanic (i.e. non-adaptive) partner (all $p > .51$).

Results of the ASIM revealed that SI-DMI compared to CMI increased the quantity and quality of spontaneous imitation and synchronization of movements ($p = .001$, $\eta_p^2 = 0.4$) as well as reciprocity/dialogue in movement ($p = .009$, $\eta_p^2 = .26$). Both interaction effects were driven by a significant increase of imitation/synchronization ($p < .001$, $d = 1.27$) and reciprocity/dialogue ($p = .04$, $d = 1.25$), respectively, in the SI-DMI group, whereas both parameters did not change significantly in the CMI group (imitation/synchronization: $p = .08$, $d = -.47$, reciprocity/dialogue: $p = .59$, $d = -.16$). In contrast, orientation of gaze and body towards the confederate and relation in spatial movement were not differentially affected by the two interventions (orientation: $p = .49$, $\eta_p^2 = .02$, relation in spatial movement: $p = .16$, $\eta_p^2 = .08$.

Table 11. Outcome measures at baseline and post intervention

	Synchronization and imitation based dance/movement intervention (SI-DMI)[a]					Control movement intervention (CMI)[a]					F Value	P Value[b]	Effect size[b]
Outcome	N	Baseline	Post intervention	Mean change (95 % CI)	d[c]	N	Baseline	Post intervention	Mean change (95 % CI)	d[c]			η_p^2
Emotion inference (MET)	27	16.85 (6.2)	18.67 (6.8)	1.81 (0.6 - 3.1)	0.58	24	19.13 (4.4)	19.00 (4.9)	-0.13 (-1.4 – 1.2)	0.04	3.57	.04	0.09
Empathic feelings (MET)	27	3.51 (2.0)	3.64 (2.0)	0.13 (-0.2 – 0.4)	0.15	24	3.80 (2.1)	3.85 (1.9)	-0.05 (-0.4 – 0.3)	-0.06	0.64	.43	0.01
Perspective taking (IRI)	27	11.59 (4.1)	12.33 (5.1)	0.74 (-0.6 - 2)	0.26	24	13.46 (4.7)	13.83 (5.1)	0.38 (-0.9 - 1.7)	0.11	1.17	.68	0.004
Empathic concern (IRI)	27	13.44 (5.7)	13.74 (5.3)	0.30 (-1.2 - 1.8)	0.08	24	14.67 (7.0)	15.38 (5.5)	0.71 (-0.9 - 2.3)	0.18	0.14	.71	0.003
Automatic imitation effect[d]	27	20.42(40.1)	37.88 (34.5)	17.46 (2.4 – 32.5)	0.47	23	42.55(37.5)	37.13 (32.9)	-5.42 (-21.8 – 10.9)	-0.03	4.29	.04	0.08
Asynchrony[e] with human-like (adaptive) virtual partner	19	26.80 (6.5)	24.47 (4.7)	-2.32 (-3.9 – (-0.7))	-0.63	15	28.56 (4.7)	28.95 (4.3)	0.36 (-1.4 – 2.1)	0.13	5.39	.03	0.14
Asynchrony[e] with metronome-like (non-adaptive) virtual partner	19	25.92 (6.8)	25.9 (5.5)	-0.02 (-2.0 – 1.9)	0	15	26.88 (6.8)	27.73 (6.8)	0.85 (-1.3 – 3.0)	0.21	0.38	.54	0.01
Spontaneous imitation/ synchronization (ASIM)	16	0.84 (1.3)	1.41 (1.3)	0.56 (0.3 - 0.8)	1.27	9	1.22 (1.0)	0.89 (0.7)	-0.33 (-0.7 - 0.1)	-0.47	15.33	.001	0.40
Reciprocity/dialogue (ASIM)	16	0.34 (0.4)	0.88 (0.6)	0.53 (0.3 - 0.8)	1.25	9	0.83 (0.7)	0.88 (0.6)	-0.11 (-0.5 - 0.3)	-0.16	8.25	.009	0.26
Gaze and body orientation (ASIM)	16	1.69 (1.8)	1.88 (1.9)	0.18 (-0.5 - 0.1)	0.27	9	1.44 (0.8)	1.44 (1.0)	0.0 (-0.4 - 0.4)	0	0.49	.49	0.02
Relation in spatial movement (ASIM)	16	1.16 (2.0)	1.56 (2.1)	0.41 (0.0 - 0.9)	0.43	9	0.94 (0.8)	0.83 (0.9)	-0.11 (-0.7 - 0.5)	-0.47	2.09	.16	0.08

Table 11continued

Abbreviations: CI, confidence interval; MET, Multifaceted Empathy Test; IRI, Interpersonal Reactivity Inventory; ASIM, Assessment of Spontaneous Interaction in Movements.

[a]Baseline and post intervention data are means (SD) from ITT analyses (carry forward).

[b]P values and effect sizes (η_p^2) refer to time*group interactions from mixed model ANOVAs.

[c]Cohen's d, effect size for the change from baseline to post intervention within each group.

[d]Difference between reaction times in the compatible and baseline conditions in milliseconds.

[e]SD of asynchronies between the participant’s tap and their virtual drumming partner’s tone in milliseconds, higher values reflect poorer performanc

3.4.5 DISCUSSION

A dance/movement intervention based on interpersonal movement imitation and synchronization (SI-DMI) was effective in fostering emotion inference in adults with high-functioning ASD compared to a control movement intervention (CMI) focusing on individual movement tasks. On a close generalization level, the SI-DMI group showed increased imitation tendencies and enhanced synchronization abilities compared to the CMI group.

In the primary outcome measure, the Multifaceted Empathy Test (MET), the SI-DMI group showed an increase in emotion inference but not in empathic feelings compared to the CMI group. The effect of SI-DMI on emotion inference is in line with previous research, relating imitation, top down modulation of imitation (imitation inhibition), and interpersonal movement synchronization to socio-*cognitive* processes including emotion recognition and mentalizing (Brass et al., 2009; Fairhurst et al., 2013; Oberman, Winkielman, & Ramachandran, 2007; Stel & van Knippenberg, 2008; Yun, Watanabe, & Shimojo, 2012). In contrast to our study, previous research has also suggested that imitation and synchronization increase socio-*affective* processes such as liking and affiliation (for a review cf. Chartrand & Lakin, 2013). An explanation for the null effect on empathic feelings found here could be that imitating and moving in synchrony with other individuals influence affective states such as liking, affiliation, and empathic feeling in the situation, i.e., on the state level, directed specifically towards the individuals that were interacted with. In contrast, a skill such as emotion inference refers to a learned process that can be applied to other situations more easily. This might explain why in the post treatment assessment, changes could only be observed in emotion inference but not empathic feelings. No changes in perspective taking or empathic concern were measured with the IRI. Questionnaires, however, demand high introspection (Scheier & Carver, 1977), which has been reported reduced in ASD (Happé, 2003). Future studies should include follow-up assessments to ascertain whether effects extend to subjectively perceived changes in social cognition as time passes.

On the close generalization level we found an increase in the tendency to automatically imitate movements in the SI-DMI group but not in the control group. In addition, the ability to synchronize movements was increased in the SI-DMI group compared to controls when interacting with a virtual human-like partner, but not when interacting with a non-adaptive mechanic virtual partner, which further underlines the social nature of the changes observed in sensorimotor functions. These changes were corroborated by the ecologically more valid ASIM assessment, showing that also on the whole-body level imitation and synchronization as well as movement reciprocity and dialogue increased in the SI-DMI group compared to the CMI group. In sum, these effects show that SI-DMI indeed enhanced interpersonal imitation and synchronization. Importantly, they also suggest that an increase of quantity and quality of imitation/synchronization might underlie the observed increase in emotion inference.

Existing social interventions for adults with ASD such as *"Mind Reading"* (Golan & Baron-Cohen, 2006) or *"PEERS for young adults"* (Gantman, Kapp, Orenski, & Laugeson, 2012) mostly focus on teaching the understanding of others' minds, e.g. emotions, explicitly: they rely heavily on compensatory strategies and intellectual functions (Golan & Baron-Cohen, 2006) and explicit rule-based learning (Bishop-Fitzpatrick et al., 2013; Gantman et al., 2012; Golan & Baron-Cohen, 2006). Those interventions are thus of limited applicability for individuals with ASD and intellectual disability. SI-DMI, in contrast, focuses on synchronization and imitation of movements, which do not demand explicit cognitive strategies, thereby reducing the cognitive strain in social situations. Thus, although only adults with high-functioning ASD were included in the present study, we believe that individuals with low intellectual functioning might benefit from the intervention in an adapted form as well. Further research is needed to confirm the appropriateness and effectiveness of SI-DMI in cognitively more impaired individuals with ASD.

By targeting social cognitive functions directly most interventions remain agnostic with respect to associated mechanisms that might be promising in mitigating respective dysfunctions in ASD. SI-DMI focuses on imitation and synchronization as likely precursors of emotion inference and empathic feelings. In showing that our intervention indeed generalizes beyond motor functions to emotion inference we might speculate about mechanisms capable of enhancing social deficits more generally. Basic research points to at least 3 potential mechanisms that may have contributed to the observed effects of SI-DMI: Imitation, top-down modulation of imitation (imitation inhibition) and interpersonal movement synchronization (Brass et al., 2009; Chartrand & Lakin, 2013). Since all three aspects were combined in SI-DMI, this study does not allow disentangling whether the observed effects were due to one of these mechanisms or their combination. Future research should focus on linking specific interpersonal motor patterns to specific social-cognitive functions to allow for more targeted dance/movement interventions to be developed that mitigate social dysfunctions. For instance, evidence is particularly strong for a link between synchronization and socio-affective consequences (Catmur & Heyes, 2013; e.g., Wiltermuth & Heath, 2009). In contrast, imitation and imitation inhibition have been specifically linked to socio-cognitive functions, i.e., emotion recognition and perspective taking, respectively (Brass et al., 2009; Oberman et al., 2007; Santiesteban, White, et al., 2012; e.g., Stel & van Knippenberg, 2008), which should be explored in more detail.

Our study is limited by the focus on one measure of emotion inference and restriction to high-functioning adults with ASD. Since results were partly marginal and not controlled for multiple comparisons they need replication, especially with longer follow-up periods, to verify the efficacy of SI-DMI before it can be recommended for clinical use. In addition, while we found it important to complement our objective, computer-based tests of imitation and synchronization with in a more ecologically valid and qualitative measure, results from the ASIM are limited because the rater was not blind to group allocation. This being said, our study also has several strengths, as we kept a number of important aspects constant between SI-DMI and the control intervention such as setting, structure of the sessions, use of music, and homework assignments. Unlike other studies we did not only rely on self-report measures in individuals with ASD, but also objective and possibly more valid computer-based measures of social functions and imitation/synchronization, complemented by more naturalistic movement analyses. In addition our sample was larger than most comparable studies and all participants were blinded.

Taken together, we found that a dance/movement intervention focusing on interpersonal imitation and synchronization increased emotion inference beyond enhancing imitation and synchronization functions. This suggests that interpersonal motor coordination functions might be a promising means towards treating core social cognitive deficits in ASD, which warrants further investigation.

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3.4.7 APPENDIX TO STUDY 6

Additional Methods and Results

Automatic Imitation Paradigm.. We used the Automatic Imitation Paradigm (M Brass, Bekkering, Wohlschläger, & Prinz, 2000) as it has been previously described elsewhere (Cook & Bird, 2011, 2012). Participants rested their right hand on a computer keyboard, with their index and middle finger holding down two adjacent keys, and were instructed to lift their index or middle finger as soon as they saw the number 1 and 2, respectively, appear on screen. Reaction times (RTs) of finger movements were measured. Concurrently, participants saw a task-irrelevant video of a human hand in vertical orientation, performing either a congruent movement (i.e., the participant was required to make an index finger response and observed an index finger action) or incongruent movement (e.g. the participant was required to make an index finger response and observed a middle-finger action). Video clips consisted of five frames, the first of which was displayed for a variable interval of 800-2,400 ms. Frames two and three were displayed for 34 ms each and frame four for 500 ms, thus appearing as a short video clip. The fifth frame (in the color of the background) remained on screen until the duration of the trial had reached 3,000 ms and the participant had returned both fingers to the keys. The moving hand was presented in 50% of the trials, whereas the other 50% of trials comprised a three-frame 'baseline' video clip in which the fingers remained static and either the compatible or incompatible finger acquired a green mask, enabling acquisition of baseline RTs for index and middle finger movements independent of imitation. RTs from compatible and incompatible static trials were averaged to form the baseline condition. Automatic imitation was calculated as the difference in reaction time (RT) on congruent movement trials and static baseline trials. 120 trials were presented in pseudo-random order resulting in approximately 15 min task duration. Participants received standardized instructions and practiced the imitation task until they made 5 correct consecutive responses. Following previous reports (Cook & Bird, 2011), error-trials and trials with RTs < 150 ms and RTs > 2,000 ms were removed from the analysis.

Previous studies used the difference of incompatible – compatible trials as a measure for automatic imitation (Spengler, Bird, & Brass, 2010) not allowing to differentiate between automatic imitation and the ability to inhibit imitation in incompatible trials. In fact, some studies have even used the same measure (i.e., RT in incongruent – congruent trials) to measure imitation *inhibition* (Marcel Brass, Ruby, & Spengler, 2009). Therefore, we chose to use the difference of the baseline and the compatible trials as a measure of pure automatic imitation in this study. Using the method used in previous studies, i.e., a 2 (compatible vs incompatible) x 2 (pre vs post intervention) x 2 (SI-DMI vs CMI) ANOVA, yielded the same pattern of results. Most importantly, the marginally significant three-way interaction ($p = .098$, $\eta_p^2 = .06$) was driven by the SI-DMI group, in which imitation increased significantly in the compatible condition as shown by faster RTs to compatible hand movements (pre: RT = 518.56 ms, post: RT = 497.22 ms, mean difference = -21.34 ms, 95 % CI [-41.56 – (-1.11), p = .04] but did not change in the incompatible condition (pre: 549.27 ms, post: 553.36 ms, mean difference = 4.08, 95 %CI [-11.74 – 19.92]). In the CMI group in contrast, RTs did not change in either condition between pre and post intervention assessment (compatible, pre: RT = 502.44, post: RT = 502.73, p = .98; incompatible, pre: RT = 542.55 ms, post: RT = 542.67 ms, p = .99). Thus these analyses confirm that SI-DMI but not CMI enhances automatic imitation.

Interpersonal Synchronization Task. The interpersonal synchronization task used here stems from a line of basic research on interpersonal movement synchronization that applies sensorimotor synchronization paradigms in which a person synchronizes movements - such as finger taps - with human or virtual partners (Kelso, de Guzman, Reveley, & Tognoli, 2009; Konvalinka, Vuust, Roepstorff, & Frith, 2010; Tognoli, Lagarde, DeGuzman, & Kelso, 2007). The finger tapping task has been developed specifically to investigate dynamic human interactions as they occur during group music making and dance (Fairhurst, Janata, & Keller, 2013; Repp & Keller, 2008). In our version of the paradigm, participants heard via headphones the bongo drum of virtual drumming partners (VPs) with which they were asked to finger tap in synchrony while attempting to maintain the given tempo (Figure 12). VPs consisted of a pacing signal programmed to be either humanlike (i.e., variably adaptive to the participant's performance) or mechanic like a metronome. Humanlike behavior was simulated by programming the pacing signal such that it varied the onset of its tones by a given proportion (α) of the amount of asynchrony between its tones and the taps of the participant (adaptive VPs). The degree of phase correction varied between $\alpha = 0.25$, $\alpha = 0.75$, and $\alpha = 1$ to simulate a range of flexible adaptivity. Thus, a negative registered asynchrony (participant's tap preceded the bongo tone) resulted in a shortening of the next sequence inter onset interval (IOI, i.e., the next tone occurring sooner). Similarly, if the participant's tap occurred after the tone, a positive asynchrony was registered resulting in a lengthening of the next IOI. Thus, the direction of phase correction shown by the adaptive VPs was the opposite of the correction expected in the participant's taps, as it happens in cooperative human interaction. In contrast, the mechanic, metronome-like pacing signal was kept a steady pace irrespective of the participant's behavior (non-adaptive VP,.$\alpha = 0$).

The VP was implemented as an auditory pacing signal generated online by a program written in MAX 4.5.7 (http://www.cycling74. com). The tones were specified to be 50 ms in duration played as synthesized "bongo drum" sounds. Participants wore headphones and were instructed to tap with their right index finger on an in-house built tapping pad that was connected to the computer via a MIDI interface. Ten blocks of 37 tones per condition of VP adaptivity were presented in a pseudo-randomized order, resulting in a total of 40 blocks, that participants could start by pressing the space bar at their own tempo. Each block consisted of two isochronous initiation pacing tones (IOI of 500 ms) and, starting with the third tone, subjects were instructed to tap in synchrony with the pacing signal. The paradigm was explained through written instructions and participants performed 4 training blocks, i.e., one block per condition, before starting with the first experimental block. Participants were told that they would always be interacting with *virtual* drumming partners but that these were all programmed to act like human partners.

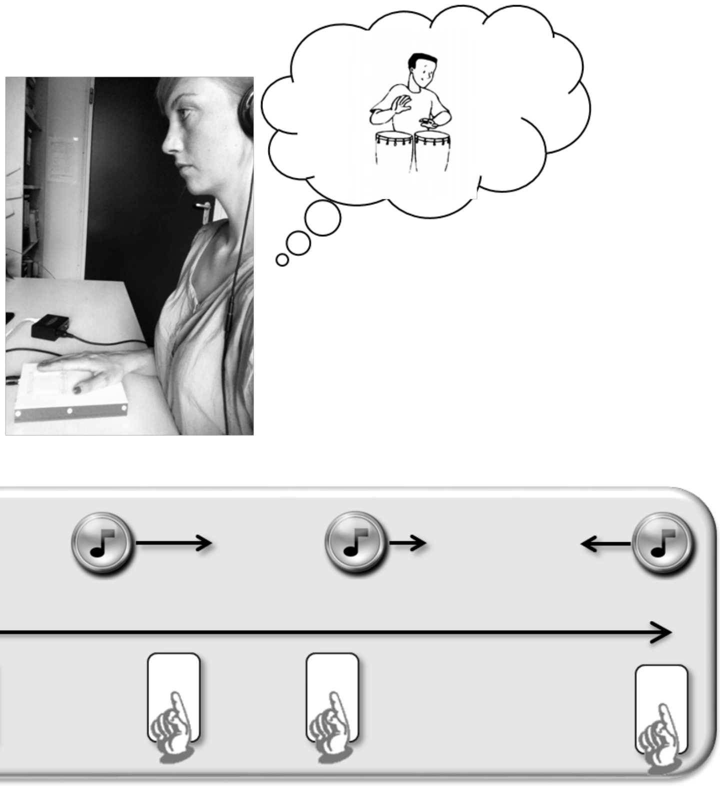

Figure 12. Illustration of the interpersonal synchronization task.
Participants were asked to tap with their index finger on a tapping pad in synchrony with virtual partners, who adapted their bongo beats to the partner's tempo to varying degrees. The individual displayed in this figure is the first author S.K..

Computer tone and human tap timings were analyzed in terms of asynchronies, or differences between tap and tone onsets (i.e. tone onset times were subtracted from tap onset times, yielding negative asynchronies when taps preceded tones). The standard deviation of asynchronies between taps and tones (SD asynchrony) served as measure for synchronization performance whereby high values of SD asynchrony indicate poor performance (Repp & Keller, 2008). SD asynchrony from interactions with adaptive VPs were averaged to form a measure of synchronization with human-like (adaptive) partners as compared to metronome-like (non-adaptive) partners.

Table 12. Example criterion of ASIM: Imitation and synchronization (excerpt)

Imitation and synchronization of/with confederate's movements	Qualitative and quantitative coding considering: a) frequency b) quality/ modulation/ grade of variation 0 = Proband shows no imitation of confederate's movements (= no interaction via imitation). • The proband moves independently from the confederate without visible relation to confederate in terms of imitation 1 = Proband shows imitation of confederate's movements to a small degree (= hinted interaction via imitation). • Occasional and/or hinted imitation of confederate's movements (=at least one change between own/independent movement and imitation). 2 = Proband shows marked imitation of confederate's movements, not or marginally modulated (= marked and simple interaction via imitation). • Repeated (at least twice per task), marked imitation of confederate's movements, including either at least one longer passage (lasting for more than one movement), or at least 3 shorter passages, possibly as synchronized movement (=at least 2 changes between own/independent movement and imitation/synchronisation). At least one passage of imitation has to appear in close temporal relation to confederate. 3 = Proband shows marked and modulated imitation and synchronization of confederate's movements (= marked and modulated/differentiated interaction via imitation). • Frequent (at least 3x per task) and marked imitation of confederate's movements, including at least one longer passage (lasting more than one movement) with one or more passages in close temporal relation to confederate, partly with synchronization of movements. AND: proband varies observed and imitated movement markedly, including and alternating with elements of variation and contrast in own movement.

All ASIM criteria are rated in consideration of frequency and quality on a scale from 0-3. As central part of the conceptualization of the coding system, coding of each of the four observed interactive phenomena from 0 to 3 corresponds to an increasing quality of interaction in movement made possible by the proband. The manual comprises detailed instructions and examples.

Table 13. Complete case analyses[e]: Outcome measures at baseline and post intervention

	Synchronization and imitation based dance/movement intervention (SI-DMI) [a]					Control movement intervention (CMI) [a]					F Value	P Value[b]	Effect size[b]
Outcome	N	Baseline	Post intervention	Mean change (95 % CI)	d[c]	N	Baseline	Post intervention	Mean change (95 % CI)	d[c]			η_p^2
Emotion inference (MET)	25	16.23 (6.1)	18.24 (6.9)	1.96 (0.64 - 3.28)	0.61	23	19.30 (4.4)	19.17 (5.0)	-0.13 (-1.50 - 1.24)	-0.04	4.90	.03	0.10
Empathic feelings (MET)	25	3.47 (2.0)	3.61 (1.96)	0.14 (-0.19 - 0.47)	0.16	23	4.02 (2.0)	3.98 (1.8)	-0.05 (-0.39 - 0.29)	0.07	0.65	.43	0.01
Perspective taking (IRI)	25	11.32 (3.8)	12.12 (4.93)	0.80 (-0.50 - 2.10)	0.27	23	13.30 (4.8)	13.70 (5.2)	0.39 (-0.96 - 1.74)	0.11	0.19	.66	0.004
Empathic concern (IRI)	25	13.28 (5.8)	13.60 (5.4)	0.32 (-1.33 - 2.0)	0.08	23	14.87 (7.1)	15.60 (5.5)	0.74 (-0.98 - 2.45)	0.18	0.13	.72	0.003
Automatic imitation effect[d]	24	23.99 (38.6)	43.63 (28.8)	19.64 (3.02 - 36.26)	0.50	22	39.15 (34.6)	33.48 (28.5)	-5.67 (-23.03 - 11.68)	-0.14	4.51	.04	.09

Abbreviations: CI, confidence interval; MET, Multifaceted Empathy Test; IRI, Interpersonal Reactivity Inventory.

[a]Baseline and post intervention data are means (SD). Because of the smaller N, the outcome measures for interpersonal synchronization and the Assessment of Spontaneous Interaction in Movements do not differ from the ITT analyses reported in the main text.

[b]P values and effect sizes (η_p^2) refer to time*group interactions from mixed model ANOVAs.

[c]Cohen's d, effect size for the change from baseline to post intervention within each group.

[d]Difference between reaction times in the compatible and baseline conditions in milliseconds. Data from one SI-DMI participant post interventions was lost due to technical reasons. One CMI subject was excluded because he showed prolonged reaction times (> 3 SD from group mean) across all conditions at post intervention assessment.

Table 14. ITT analyses following multiple imputation[c]: Outcome measures at baseline and post intervention.

	Synchronization and imitation based dance/movement intervention (SI-DMI) [a]			Control movement intervention (CMI) [a]			F Value	P Value[b]	Effect size[b]
Outcome	N	Baseline	Post intervention	N	Baseline	Post intervention			η_p^2
Emotion inference (MET)	27	16.85 (6.23)	18.87 (6.99)	24	19.13 (4.42)	18.90 (5.04)	5.87	.02	0.12
Empathic feelings (MET)	27	3.51 (2.02)	3.65 (1.92)	24	3.90 (2.06)	3.88 (1.85)	0.41	.53	0.01
Perspective taking (IRI)	27	11.59 (4.09)	12.30 (5.37)	24	13.46 (4.71)	13.64 (5.20)	0.30	.59	0.01
Empathic concern (IRI)	27	13.44 (5.71)	13.67 (5.48)	24	14.67 (7.04)	15.48 (5.46)	0.26	.61	0.01
Automatic imitation effect[d]	27	20.42 (40.06)	43.98 (30.76)	24	41.82 (36.86)	37.62 (33.43)	4.03	.05	0.08

Abbreviations: MET, Multifaceted Empathy Test; IRI, Interpersonal Reactivity Inventory.

[a] Baseline and post intervention data are means (SD). Because of the smaller N, the outcome measures for interpersonal synchronization and the Assessment of Spontaneous Interaction in Movements do not differ from the ITT analyses following last observation carried forward imputations reported in the main text.

[b] P values and effect sizes (η_p^2) refer to time*group interactions from mixed model ANOVAs.

Note. We report ITT analyses following multiple imputation as an alternative way of handling missing data. The multiple imputation procedure offered by IBM SPSS Statistics 21 was used to produce 5 data sets using the monotone multiple imputation algorithm implemented in SPSS. The imputation model included the MET, IRI, and imitation variables at both time points, the treatment indicator, as well as age, sex and IQ. The F-tests of the repeated-measures ANOVA were pooled using the approach set forth by (van Ginkel & Kroonenberg, 2014). SDs and η_p^2 were pooled after log-transformation and square root transformation, respectively, following the recommendations provided by (Enders, 2010). Results are similar to those from ITT analyses following last observation carried forward imputation reported in the main text.

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4 GENERAL DISCUSSION

4.1 DISCUSSION OF PART I. THE ROLE OF INTERPERSONAL SYNCHRONIZATION IN EMPATHIC FUNCTIONS IN NEUROTYPICAL INDIVIDUALS

In preparation of the characterization of the association of imitation/synchronization and empathy in ASD (part II) the central aim of part I of this dissertation was to characterize the link between interpersonal synchronization and empathic functions in neurotypical populations. As a crucial step towards this aim, an attempt was made in study 1 to develop an up-to-date measure (CEEQ) to adequately assess different subcomponents of empathy. In study 2, through the investigation of empathy in experts of interpersonal synchronization (Capoeira players and Tango dancers) and non-experts (Breakdancers and Salsa dancers) using the newly developed CEEQ, it was possible to gain support for an association of synchronization and higher-order empathy components. Specifically, an increase in kinesthetic empathy in expert synchronization groups was demonstrated, which was associated with cognitive and emotional empathy and might thus represent a precursor of these components.

In study 1, a new, timely self-rating measure for cognitive and emotional empathy was developed and evaluated crucially aiming at two renovations: 1) To take into account current research on the role of imitation and synchronization of observed movements as potential precursors of empathic functions and 2) in preparation of part II of this dissertation to meet the specific language needs of individuals with ASD. In pursuit of point 1), the CEEQ not only includes two traditionally investigated aspects of empathy (empathic concern and perspective taking), but also adds the tendency to spontaneously experience emotions that are observed in another individual (emotion mirroring) and the ability to recognize and identify the emotions and mental states of other people from observable cues such as facial expressions and body language (mental state perception). The advantage of these newly developed scales is that they refer to situations where the responder deduces a mental state from the physical state of the observed person. For example, a mental state perception item states: "I am good at reading other people's facial expressions" and another one "I can easily tell if someone is interested in what I am saying based on her/his body language". Similarly, emotion mirroring items refer to sharing an emotion triggered perception of direct emotion expression (rather than verbal accounts thereof), e.g., "When I see someone crying because she/he is sad, it also makes me sad" and "Hearing other people laugh makes me want to laugh too". Thus, the CEEQ subscales were hypothesized to be more closely related to its embodied precursors (imitation/synchronization) than traditional empathy scales. Overall, the four individual subscales of the Cognitive and Emotional Empathy Questionnaire (CEEQ) showed adequate psychometric properties in terms of internal consistency and reliability. The validity of the CEEQ as a multi-dimensional measure of empathy was supported by converging correlations with existing empathy measures, predictable correlations with related psychological measures and by the results of an exploratory factor analysis.

The second renewal was to adapt the CEEQ for individuals with ASD, i.e. a population that is impaired in verbal communication. One important step towards this goal was avoiding figurative language such as metaphor and simile. Other empathy questionnaires use figurate language to a large extend, such as “soft-hearted person,“ “put myself in his shoes,“ and “I go to pieces“ (Davis, 1983). Difficulties in answering questionnaires may explain at least partly conflicting findings showing decreased emotional empathy in ASD in self-report questionnaires but unimpaired emotional empathy in objective measures (Bird et al., 2010; Blair, 2005; Dziobek et al., 2008). Thus although the CEEQ still awaits evaluation in ASD populations, by avoiding figurative language the CEEQ might proof to be a more accurate measure of empathy in this population and other populations with pragmatic language difficulties.

In sum, the CEEQ in general and the subscales for emotion mirroring and mental state perception more specifically turned out to be promising measures to capture empathy multidimensionally with a focus on those subcomponents that are conceptually closer related to kinesthetic empathy than traditionally empathy scales. While application in ASD groups and longitudinal designs await further evaluation, study 1 suggests that an application of the mental state perception and emotion mirroring subscales to investigate the association of synchronization and subcomponents of empathy in neurotypical populations is warranted.

Study 2 built on study 1 by making an effort to use the 2 newly developed CEEQ scales measuring emotion mirroring and mental state perception to assess the association between interpersonal movement synchronization and subcomponents of empathy in neurotypical populations. We investigated how repetitive training of dynamic, mutual synchronization affects kinesthetic, emotional, and cognitive aspects of empathy in individuals practicing Tango and Capoeira, which crucially depend on high degrees of interpersonal movement synchronization. Tango dancers and Capoeira players were contrasted with practitioners in Salsa and Breakdance, respectively, which are similar in movement qualities and setting but entail less interpersonal movement synchronization.

As expected, the Tango and Capoeira groups reported higher kinesthetic empathy than did the Salsa and Breakdance groups. These findings indicate that practicing dynamic interpersonal movement synchronization in the course of physical practices, is associated with higher kinesthetic empathy. Two conclusions from these results are of particular importance in the context of this dissertation: Firstly, practicing dynamic and complex whole body movements as in Tango and Capoeira seems to be related to synchronization and imitation on a much broader level such as the tendency to simulate facial expressions, gestures, and physical states, like body tension, in everyday life. Thus, these results directly support the hypothesis set forth in this dissertation that mutual synchronization is related to the broader concept of kinesthetic empathy. Secondly, in contrast to previous studies which manipulated the degree of synchrony to measure the effect on social processes in the *situation*, i.e., on the state level (e.g., Hove & Risen, 2009; Valdesolo, Ouyang, & DeSteno, 2010; Wiltermuth & Heath, 2009), study 2 is an attempt to investigate effects of interpersonal synchrony on the capacity for empathy as a stable individual characteristic, i.e., on the trait level. Importantly, study 2 suggests that only mutual, dynamic synchronization enhances empathic functions on the trait level. *Rigid* synchrony in contrast, i.e., synchrony that emerges because individuals synchronize to an external pace maker rather than to each other, did not seem to have this effect. In addition, when looking only at more experienced practitioners, i.e., those who likely rely less on fixed patterns but have learned to improvise more freely and thus to synchronize their movements to their partner, the group effect on kinesthetic empathy tended to be higher compared to the whole sample, which further speaks for the importance of mutuality in synchronization.

These findings crucially inform study 6 in which the efficacy of an imitation and synchronization-based dance/movement intervention to foster empathic functions in adults with ASD is explored. Based on the findings from part I, the intervention focused in particular on *mutual*, dynamic forms of interpersonal synchronization rather than on synchronization to music and rhythm. Interestingly, in line with the results of our study indicating that Tango Argentino might be particularly suitable to foster ongoing mutual adaptation in movement and thus empathic functions, a pilot project offered a Tango Argentino program for individuals with ASD and their relatives, that according to subjective reports enhanced social communication (Walter, n.d.).

Another aim of this dissertation was to investigate effects of interpersonal movement synchronization on cognitive and emotional empathy. No group differences with regard to the tendency to mirror an affective state and the ability to infer mental states were found in study 2, questioning a relation between those constructs. Correlational analyses did, however, reveal that kinesthetic empathy was related to emotional empathy in all groups and to cognitive empathy in the synchronization-heavy Tango and Capoeira groups. These results are in line with the hypothesis that interpersonal synchronization is a precursor for emotional and cognitive components of empathy. In addition, all associations between kinesthetic empathy and emotional and cognitive empathy, albeit not reaching significance in direct comparisons, were higher in the synchronization-based practices (Tango, Capoeira) as compared to practices not depending crucially on interpersonal synchronization (Salsa, Breakdance). This again corresponds to the hypothesis that kinesthetic empathy may provide the scaffolding for higher levels of empathy. Yet, study 5 uses a highly reduced, experimental design to investigate this aspect further and corroborate the correlational findings found in study 2.

On a more general note part I advances research opportunities on the embodied process underlying empathy in three ways. Firstly, the approach of conducting field studies to investigate populations that naturally differ in their degree of synchronization and imitation offers a way to circumvent the effort and costs involved in longitudinal training studies while being more naturalistic and thus ecologically valid than laboratory experiments. Secondly, assessing individuals with a circumscribed superiority in synchronization rather than focusing only on populations with a potential deficit in this function such as autism opens new ways to investigate embodied empathy and may lead to a more complete picture of this important function. Thirdly, measuring kinesthetic empathy through a valid self-report measure rather than effortful physiological or behavioral measures may help advance future research beyond the studies reported here by enabling collecting large samples in different places. For instance it would be interesting to examine cultural differences of kinesthetic empathy, as it has been shown that the amount of gestures and thus embodied ways of conveying emotions varies between cultures (So, 2010). Another route for future research would be to look at the effects of interpersonal synchronization in groups in ecologically valid settings while trying to manipulate the degree of synchrony experimentally. For instance, participants blind to the study goal could be invited to a "silent disco" event, where people hear music via headphones with varying degrees of synchrony. In addition to effects on the individual trait level, effects on the group level could be assessed in this setting such as group cohesion, which has been suggested to be a group-level consequence of synchronous behavior (Camilleri, 2002). In sum, several new research ideas may spring from the approach presented in study 2.

With respect to the specific aim of part I to provide evidence for an association between interpersonal synchronization and empathic functions in healthy individuals, first important steps were taken. Together, the results of study 1 and study 2 suggest that interpersonal synchronization may provide the scaffolding for cognitive and emotional empathy potentially mediated by kinesthetic empathy. Since no causal inferences can be made from this very naturalistic field study, well-controlled experimental manipulations of synchrony in a laboratory setting should be investigated next. In addition, part I paves the way for an investigation of the association between kinesthetic and cognitive/emotional empathy in individuals with ASD which was attempted in part II.

4.2 DISCUSSION OF PART II. THE ROLE OF INTERPERSONAL SYNCHRONIZATION IN EMPATHIC FUNCTIONS IN AUTISM SPECTRUM DISORDER

Part II of this dissertation attempts to characterize the association between imitation/ synchronization and empathic functions in individuals on the autism spectrum. Two highly controlled experimental cross-sectional studies investigating, respectively, the imitation and synchronization specificities of individuals with ASD compared to without ASD were complemented by a controlled longitudinal design to further establish the causal nature of the link between imitation/synchronization and empathy functions. Insights from all studies of this dissertation culminate in the development and evaluation of an imitation and synchronization based dance/movement intervention to foster empathy in adults with ASD.

As a starting point for investigations of the association of subcomponents of empathy in ASD, study 3 made an effort to review and summarize the accumulating findings on the neural correlates of ASD symptomatology, both functional and structural, with a focus on social cognition. While there was broad consensus that deficits in emotional face processing were associated with aberrant functioning of the fusiform gyrus, the amygdala and the superior temporal sulcus, deficits in cognitive empathy were more controversially ascribed to malfunctioning of either the so-called mirror neuron system or the so-called theory of mind network. More generally, aberrant fronto-parietal connectivity seemed to be among the most robust results from neuroimaging studies, explaining at least partly impairments in language, executive functions and central coherence associated with ASD.

Since it has been a controversial debate whether a general imitation deficit based on a broken mirror neuron system (broken mirror theory, BMT, cf. section 1.5) can explain empathy deficits in ASD, study 4 made an effort to investigate cross-sectionally, whether imitative behavior is reduced in individuals with ASD. Experiment 1 utilized a test of automatic imitation in a much larger sample of adults with ASD than obtained in previous studies, and revealed automatic imitation to be intact in individuals with ASD and comparable to that demonstrated by a neurotypical control group. To exclude the alternative explanation that performance on the task used in Experiment 1 was affected by orthogonal spatial compatibility, potentially masking any group differences in automatic imitation, Experiment 2 used a novel task allowing the independent manipulation and measurement of both automatic imitation and spatial compatibility. This allowed the observation that automatic imitation effects persist regardless of spatial compatibility in both individuals with ASD and typical control individuals. While again, no group differences in automatic imitation were observed, automatic imitation was positively correlated with autism symptom severity. Since this paradigm measures automatic imitation in terms of the ability to overcome (i.e., inhibit) an automatic imitative reaction, this correlative result rather hints at *excessive* automatic imitation in ASD, suggesting that the *inhibition* of imitation is deficient in ASD.

Study 4 demonstrates, contrary to the prevailing view (J.H.G. Williams, Whiten, Suddendorf, & Perrett, 2001; Justin H G Williams, Whiten, & Singh, 2004) that individuals with autism show intact imitative behavior. As discussed in study 4 (section 3.2.9), it has been shown that automatic imitation effects rely on the mirror neuron system (Catmur, Walsh, & Heyes, 2009; Heiser, Iacoboni, Maeda, Marcus, & Mazziotta, 2003; Heyes, 2011), so that these data suggest that the BMT of autism is unlikely to be a valid explanation of the broad deficits in ASD.

While study 4 did not find group differences in automatic imitation, a positive correlation of automatic imitation and autism symptom severity was observed. This finding is in line with previous investigations showing hyper imitative performance in ASD (Bird, Leighton, Press, & Heyes, 2007; Spengler, Bird, & Brass, 2010). As discussed in study 4 (section 3.2.9), an alternative approach to BMT involves conceptualizing ASD as disorder of top-down modulation of social cognition, which is in line with the correlative results found here. Indeed, imitation *inhibition* has been found to be associated with social cognitive abilities in neurotypical individuals (cf. section 1.3.2). In accord with this notion, modulatory effects of pro-social priming on automatic imitation in neurotypical individuals were absent in those with ASD (Cook & Bird, 2012). Similarly, hyper-imitation was found to be correlated with impaired theory of mind in these individuals (Spengler, Bird, et al., 2010). Hence, a deficiency within a neural network which supports the top-down control of representations of “self” and “other” seems plausible in ASD and would account for hyper-imitation as well as impairments in empathic functions in these individuals. One such neural network suggested to subserve this role in the human brain involves the medial prefrontal cortex and temporoparietal junction (Brass, Derrfuss, & von Cramon, 2005; Santiesteban, Banissy, Catmur, & Bird, 2012; Spengler, von Cramon, & Brass, 2010).

The finding that imitative behavior and mirror neuron function per se are intact in ASD and unlikely to contribute to the social deficits may call into question efforts to develop an intervention aiming at fostering empathic functions in ASD through an imitation and synchronization-based dance/movement intervention (study 6). However, even if imitation is not impaired per se, the translation into empathic functions may be attenuated, making it worthwhile to investigate the *association* between imitation and empathic functions further. In addition, since the link between imitation and pro-social functions is well-documented in neurotypical individuals (for a review, cf. Chartrand & Lakin, 2013), the enhancement of flexible, socially adaptive imitation should have a positive effect on empathic functions independent of a general deficit in one of these functions. In fact, if imitation abilities / mirror neuron functions were completely absent in individuals with ASD, attempts to use imitation as a leverage to foster empathy would be pointless. Thus findings of intact imitation abilities do not speak against the use of imitation-based techniques in interventions to foster empathy in individuals with ASD. Instead, they support an approach, which aims at fostering the *socially adaptive, flexible* use of the existing imitation skills.

This approach is further corroborated by the correlative finding suggesting that imitation is *increased* in individuals with ASD and that excessive imitation is detrimental for empathic functions. In direct opposition to the BMT, this alternative view suggests that imitation *inhibition* should be trained in order to achieve a positive effect on empathic functions. This view, however, conceptualizes the underlying processes as two opposing ends of the same continuum: automatic imitation vs. imitation inhibition. However, when thinking of imitation inhibition in terms of adaptive, dynamic *modulation* of automatic imitation rather than its suppression, these two functions might be seen as working together for empathic functions to be fully functional. This model allows reconciling conflicting evidence from previous research and underlies the development of the imitation-based intervention presented in study 6. The model is laid out in greater detail in section 4.3.1. of this dissertation. Taken together, an intervention aiming at fostering empathic functions should complement exercises aiming at enhancing automatic imitation (potentially leading to simulation) with those that target modulation of imitated movements (potentially underlying thus self-other differentiation).

While study 4 focused on imitation, study 5 made an effort to investigate the influence of synchronization during interaction on empathy in NT and ASD. To that end, study 5 takes the results from the quasi-experimental field study provided in study 2 a step further by systematically manipulating the degree of synchronization during interaction to get at the causal effects on cognitive and emotional empathy. In contrast to study 2, where interpersonal synchronization happened on the whole body level during real life interaction over extended periods of time, study 5 uses the so-called "minimal synchrony paradigm" exactly because it reduces the interaction to sending simple light signals back and forth similar to Morse code or smoke signals, while excluding all other social signals such as facial expression, gestures and tone of voice. This highly controlled setting prevents confounding the results with other factors of more complex/naturalistic interaction that were shown to be processed differently by autistic individuals (Philip et al., 2010).

In an effort to further break down the complex process of interpersonal synchronization, we focused on unilateral (in contrast to reciprocal) synchronization (Cacioppo et al., 2014). In unilateral synchronization, one individual within a dyad (the follower) unilaterally adjusts his or her movements to entrain to the movements of the other individual (the leader) within the dyad, where the leader moves periodically but does not adjust his or her movements in reciprocation to promote synchrony. The more passive experience of synchrony in the leader role has been referred to as *perceived synchrony*, whereas the experience of the follower, who actively adjusts his or her movements to entrain to the movements of the leader, can be described as *produced synchrony*.

To investigate the effect of *perceived* interpersonal synchrony on cognitive and emotional empathy in individuals with and without autism, participants were asked to take the role of the leader in a beat-based communication task, while their virtual partners were programed to follow in a synchronous or asynchronous way. Analyses showed that the NT control group, but not the ASD group, reported more cognitive empathy towards their partner if the partner had followed them in a synchronous compared to an asynchronous way. The study also investigated the effect of animacy (interacting with an ostensible human player or the computer) on *produced* synchronization in those interactions, in which the participant follows in the interaction (follower task). In contrast to the hypothesis, higher synchronization was observed when participants interacted with an ostensible human partner compared to the computer. The study furthermore did not reveal differences in produced synchronization between ASD and NT participants. Interestingly though, within the ASD group, the degree of synchronization with the ostensible human partner was correlated with cognitive empathy as measured with two objective cognitive empathy tasks. Indeed, it was found that higher synchrony during the interaction was related to higher cognitive empathy. The absence of a significant correlation in the NT group was most likely explained by a lack of variance within the sample.

The finding that in non-autistic individuals perceiving a partner as interacting more synchronously leads to higher cognitive empathy towards this partner is in line with previous research showing positive social consequences of synchronous behavior such as increased rapport, affiliation, prosocial behavior, and cooperation (Bernieri, 1988; Cacioppo et al., 2014; Hove & Risen, 2009; Kirschner & Tomasello, 2010; Valdesolo et al., 2010; Wiltermuth & Heath, 2009; Chartrand & Lakin, 2013). Study 5 adds to this line of research by showing that a follower's synchronization during interaction increases the leader's subjective estimate of how much he is able to understand the thoughts and intentions of the other. It thereby corroborates the findings of study 2 that interpersonal synchrony is related to cognitive empathy. In addition, by implementing an experimental study design, the findings of study 5 take those of study 2 a step further by showing that this link is causal, i.e., that increased perceived synchrony causes increased cognitive empathy in NT populations.

In contrast to the NT group, *perceived* synchronous interaction did not increase cognitive empathy in ASD. This might indicate that synchronization does not mediate cognitive empathy in ASD to the same degree as in controls. Impairments in the link between perceived synchrony and cognitive empathy might contribute more generally to the social deficits of individuals with ASD. Previous studies (Fitzpatrick, Diorio, Richardson, & Schmidt, 2013; Marsh et al., 2013) only looked at synchronization abilities per se but not at the link to empathic or other social functions. Therefore this is the first study providing evidence that the link between synchrony and cognitive empathy might be impaired in ASD. *Produced* synchronization behavior was related to cognitive empathy performance as measured with an external objective task in the ASD group. This suggests that the mechanism linking synchronization with cognitive empathy is not *absent* in ASD, while together the results from this study speak for an attenuation of this link.

With respect to the intervention developed in study 6, these results suggest in line with the results from study 2 that an intervention aiming at fostering empathic functions should include possibilities to experience interpersonal synchrony in movement in order to aim at strengthening the adaptive link between interpersonal synchrony and empathic functions.

To conclude, study 4 yielded important information toward understanding cross sectional differences in synchronization in ASD. Importantly, the mechanism linking synchronization functions with cognitive empathy does not seem to be entirely disrupted but rather seems to be weaker. Thus, giving individuals with ASD the opportunity to experience interpersonal synchrony and foster their own synchronization abilities might enhance their ability to understand the thoughts and intentions of others.

The studies of this thesis culminate in an attempt to provide evidence for a clinical application of the imitation/synchronization-empathy link. Study 6 builds on all previous studies of this dissertation by making an effort to use the better understanding of the link between imitation/synchronization and empathic functions in general and in ASD more specifically to develop and evaluate an imitation and synchronization based dance/movement intervention (SI-DMI) for adults with ASD. Results of study 6 showed that SI-DMI was effective in fostering cognitive empathy in adults with high-functioning ASD compared to a control movement intervention (CMI) focusing on individual movement tasks. On a close generalization level, the SI-DMI group showed increased imitation tendencies and enhanced synchronization abilities compared to the CMI group.

The effect of SI-DMI on cognitive empathy is in line with previous research and the previous studies of this dissertation, relating imitation, top down modulation of imitation (imitation inhibition), and interpersonal movement synchronization to socio-cognitive processes including emotion recognition and mentalizing (Brass, Ruby, & Spengler, 2009; Fairhurst, Janata, & Keller, 2013; Oberman, Winkielman, & Ramachandran, 2007; Stel & van Knippenberg, 2008; Yun, Watanabe, & Shimojo, 2012). The increase on the close generalization level, measured through objective tasks as well as a more ecologically valid video-based measure suggests that SI-DMI indeed enhanced interpersonal imitation and synchronization. Importantly, they also suggest that an adaptive increase and an enhanced quality of imitation/synchronization might underlie the observed increase in cognitive empathy.

In contrast to study 6, previous research has also suggested that imitation and synchronization increase socio-*affective* processes such as liking and affiliation (for a review cf. Chartrand & Lakin, 2013). An explanation for the null effect on emotional empathy found here could be that imitating and moving in synchrony with other individuals influence affective states such as liking, affiliation, and empathic feeling in the situation, i.e., on the state level, directed specifically towards the individuals that were interacted with. In contrast, a skill such as emotion inference refers to a learned process that can be applied to other situations more easily. This might explain why in the post treatment assessment, changes could only be observed in emotion inference but not empathic feelings.

As discussed in study 6, the approach set forth in this dissertation has a specific advantage compared to existing social interventions for adults with ASD such as "Mind Reading" (Golan & Baron-Cohen, 2006) or "PEERS for young adults" (Gantman, Kapp, Orenski, & Laugeson, 2012). Since those interventions mostly focus on teaching the understanding of others’ minds, e.g. emotions, explicitly: they rely heavily on compensatory strategies and intellectual functions (Golan & Baron-Cohen, 2006) and explicit rule-based learning (Bishop-Fitzpatrick, Minshew, & Eack, 2013; Gantman et al., 2012; Golan & Baron-Cohen, 2006). Those interventions are thus of limited applicability for individuals with ASD and intellectual disability. SI-DMI, in contrast, focuses on synchronization and imitation of movements, which do not demand explicit cognitive strategies, thereby reducing the cognitive strain in social situations. Thus, although only adults with high-functioning ASD were included in the present study, individuals with low intellectual functioning might benefit from the intervention in an adapted form as well. Further research is needed to confirm the appropriateness and effectiveness of SI-DMI in cognitively more impaired individuals with ASD.

Objective performance scores revealed that cognitive empathy was in fact increased after participating in SI-DMI compared to CMI. In line with the initial hypothesis this suggests that synchronization and imitation mechanisms can be used to foster cognitive empathy in individuals with ASD. Changes in cognitive empathy were measured in a task that was entirely unrelated to the movement exercises used during the study, e.g. in terms of stimulus material and instruction. This is noteworthy because previous studies, aiming at fostering social cognition in adults with ASD using objective outcome measures used stimuli and tasks that were very similar to the intervention itself (e.g., Bölte et al., 2002; Chen, Lee, & Lin, 2015). Thus, the degree of generalization of the effects of those previous studies remains unclear. One study that did use well-established mind-reading tasks in addition to intervention-close material did not find a generalization of to incremental effect to those tasks (Golan & Baron-Cohen, 2006). Thus it is a particular strength of this study to show generalization of the effects of SI-DMI to social measures far beyond the actual tasks trained in the intervention.

With respect to the aim of part II, study 6 adds a longitudinal design to the previous cross-sectional studies (studies 4 and 5). By showing that a focus on interpersonal synchronization and imitation during a 10-week dance/movement intervention increased cognitive empathy functions in individuals with ASD, the results of study 6 further corroborate that the link between imitation/synchronization and empathic functions is *causal.* More specifically, 3 components were included in SI-DMI that were thought to have an effect on empathic functions: imitation, top down modulation of imitation (imitation inhibition), and interpersonal movement synchronization to cognitive empathy. While all three mechanisms have been described in previous basic research (Brass et al., 2009; Fairhurst et al., 2013; Oberman et al., 2007; Stel & van Knippenberg, 2008; Yun et al., 2012), the importance of imitation inhibition and synchronization especially when working with individuals with ASD were underlined by the previous studies of this dissertation (studies 4 and 5, respectively). Since all three aspects were combined in SI-DMI, this study does not allow disentangling whether the observed effects were due to one of these mechanisms or their combination. This dissertation suggests a parsimonious model of how all three functions might work in concert support empathic functions. This model is described in detail in section 4.3.1.

An important point to be taken from the results of study 6 in regard to this dissertation is that in line with studies 2 and 5 a link between synchronization and cognitive empathy was supported. With regard to the aim of part II of this dissertation, study 6 yielded positive results in that it further established what has been carved out in studies 4 and 5, namely, that similar to NT populations, synchronization and imitation are associated with empathic functions in individuals with ASD. Importantly, although replication is needed especially with longer follow-ups, this link seems to have the potential to mitigate deficits in cognitive empathy in individuals with ASD.

Taken together, part II revealed, based on a literature review of recent neuroscientific findings on ASD, that imitation and synchronization are largely intact in individuals with ASD but that the link between imitation/synchronization and cognitive empathy is attenuated. This association could effectively be used to mitigate deficits in cognitive empathy in those affected. With respect to neurotypical individuals, the experimental studies conducted in part II confirmed the correlative associations of part I, suggesting a link between synchronization and empathic functions.

4.3 FUTURE DIRECTIONS AND IMIPLICATIONS FOR RELATED DISCIPLINES

In this dissertation an attempt was made to show that imitation and interpersonal synchronization of movement is associated to empathic functions, and, in a second step, to characterize this link in individuals with ASD. To this end, study 1 sought to develop a timely measure of subcomponents of empathy, which was used in study 2 to compare empathic functions of synchronization experts and non-experts. It was demonstrated that expertise in synchronization is associated to higher levels of kinesthetic empathy, which in turn was correlated to cognitive and emotional empathy. Thus, although the quasi-experimental design did not allow to draw causal conclusions, these results were in line with the notion that synchronization serves as a precursor for empathic functions. On the bedrock of a social cognition - focused literature review of the neural underpinnings of ASD (study 3), studies 4, 5 and 6 assessed this association cross-sectionally and longitudinally in neurotypicals and individuals with ASD. Results of two highly controlled paradigms for automatic imitation and synchronization and a 10-week imitation and synchronization-based dance/movement intervention converged on the notion that imitation and synchronization are largely intact in individuals with ASD but that the association between imitation/synchronization and cognitive empathy is attenuated. This association, which could be confirmed to be in effect in neurotypicals, could effectively be used to mitigate deficits in cognitive empathy in those affected. This section broadens the perspective on these findings by drawing conclusions for a model of empathic functions, potential clinical applications and future research.

4.3.1 A MODEL OF EMPATHIC FUNCTIONS

The results of this dissertation speak to a controversial debate on the mechanism linking imitation/synchronization and empathic functions (Apperly, 2008; Van Overwalle & Baetens, 2009). Two opposing models have been discussed. Model one that has been proposed more than 15 years ago implies that by way of simulation, synchronization and imitation *enhance* empathic functions (Chartrand & Lakin, 2013; Gallese & Goldman, 1998; Rizzolatti, Fogassi, & Gallese, 2001). A second more recent model challenges model 1 suggesting that simulation processes are *detrimental* for empathy because they lead to egocentricity rather than perspective taking (Santiesteban, Banissy, et al., 2012; Santiesteban, White, et al., 2012) and that instead, imitation *inhibition* is what drives empathy. With regard to autism, model 1 suggests that the social deficits are caused by a general imitation/synchronization deficit in individuals with ASD, while model 2 suggests that autism is related to *hyper*-imitation caused by a lack of imitation *inhibition* (Bird et al., 2007; Dapretto et al., 2006; Press, Richardson, & Bird, 2010; Ramachandran & Oberma, 2006; Spengler, Bird, et al., 2010). Previous research has provided evidence for both models (for an overview cf. Minio-Paluello, Lombardo, Chakrabarti, Wheelwright, & Baron-Cohen, 2009; Smith, 2009).

The results of this dissertation lend partial support to both models calling for a new, third model to reconcile the results. In line with model 1 higher interpersonal synchrony led to increased cognitive empathy in neurotypical but not autistic individuals in study 5. In addition, study 6 showed longitudinally that an imitation and synchronization-based intervention led to increased automatic imitation and synchronization abilities together with enhanced cognitive empathy, suggesting in line with model 1 that imitation enhances empathic functions. However, in line with model 2, study 4 provided strong support, that automatic imitation is intact in individuals with ASD. In addition, automatic imitation was positively correlated with autism symptom severity, suggesting that deficits in imitation *inhibition* are at the cause of empathy deficits. Likewise, study 5 suggests that synchronization abilities per se were largely unaffected in ASD, speaking against a general simulation deficit. Finally, the interventions evaluated in study 6 focused not only on training imitation/synchronization but also on the modulation thereof (reciprocity in movement). Thus, it remained unclear whether imitation/synchronization or the modulation thereof caused the increase in cognitive empathy.

Adding to the controversy, each of the two models suggests a different brain network thought to support empathic functions. The neural simulation processes that according to model 1 support imitation and empathic functions by matching observed behavior with one's own behavioral repertoire, have been located in the mirror neuron system (Rizzolatti et al., 2001). While the traditional mirror neuron system thought to underlie those simulation processes consists of the inferior frontal gyrus and parietal areas (inferior parietal lobule and superior temporal sulcus), more recent research suggests that simulation is a more general mechanism supporting interpersonal processes that can also be implemented in other brain areas and may occur in form of synchronized interbrain oscillations (Lindenberger, Li, Gruber, & Müller, 2009). Imitation inhibition in contrast, which is said to be crucial for empathic functions according to model 2, was shown to rely on midline structures and the temporoparietal junction; a network that has also been called the "Theory of mind (ToM) network" (Brass et al., 2009; Santiesteban, Banissy, et al., 2012; Spengler, von Cramon, & Brass, 2009; Spengler, von Cramon, et al., 2010). Besides empathic functions, these areas have also been associated with the ability to represent the "self" and "other" (Spengler et al., 2009). Accordingly, model 2 assumes that the ability to distinguish between self and other underlies empathic functions by enabling the subject to overcome egocentricity, i.e., the tendency to project own thoughts and feelings onto others.

Taken together, the controversy between supporters of model 1 and 2 arises because simulation (imitation/synchronization), which is said to underlie empathic functions according to model 1, and self/other distinction (imitation inhibition), which is said to underlie empathic functions according to model 2, are thought to represent two opposing functions that are related to separate, independent brain systems (cf. Figure 13).

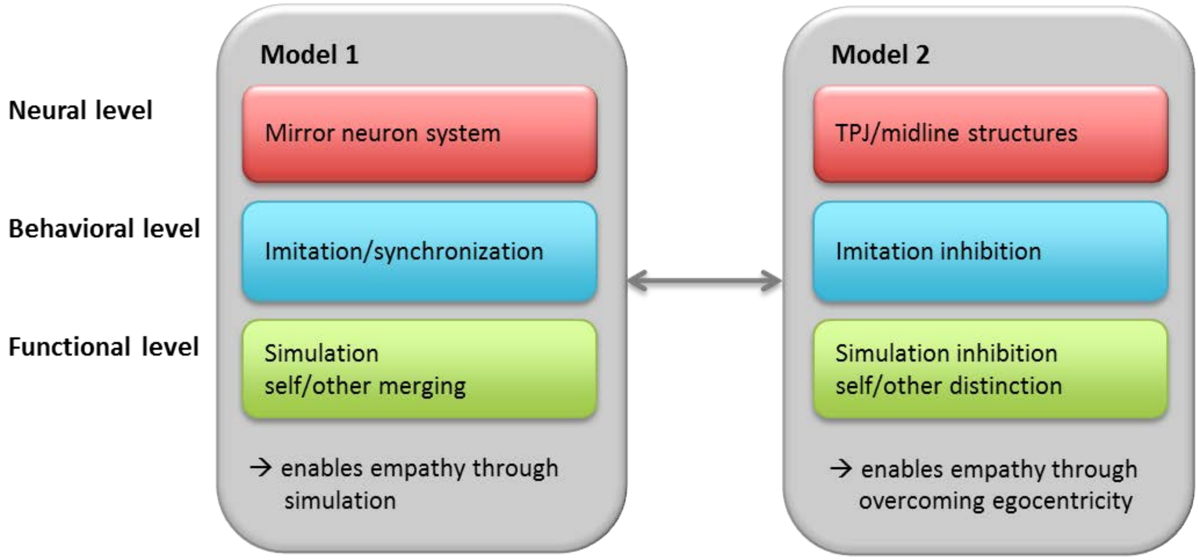

Figure 13. Two opposing models of imitation/synchronization and empathic functions (models 1 and 2). Abbreviations: TPJ = temporoparietal junction

This dissertation suggests an integrative model in which simulation and self-other distinction are thought to be complementary rather than conflicting functions, which need to work in concert for empathic functions to be fully intact. In that sense, these functions can be thought of as two orthogonal dimensions of the same model rather than two opposing models (cf. Figure 14). One important advantage is that the various subcomponents of empathy can be located and thus differentiated in the 2-dimensional integrative model (model 3) based on the degree they involve either function (Figure 14). Each subcomponent of empathy can be seen to rely to a certain degree on both, simulation and self-other differentiation, whereby the specific combination of both processes defines its characteristic. For instance, emotional contagion, i.e., catching the emotion of another person without being aware that the other was the source of that emotion, can be thought of as relying highly on simulation processes, while self-other differentiation is low in this context. Perspective taking in contrast relies heavily on self-other differentiation mechanisms, especially in situations where the other person is very different from the self. While simulation processes may add some information on the other's perspective, they play a subordinate role in the perspective taking process. Mental state perception, i.e., the ability to recognize and identify the emotions and mental states of other people from observable cues such as facial expressions and body language, could be seen as relying highly on both mechanisms: While simulation may help at gaining a first-person perspective on the physical, emotional and mental state of the observed person, strong self-other distinction is needed to identify the simulated processes as those of another person. Some more examples are depicted in Figure 14. By allowing to differentiate the subcomponents of empathy based on those 2 basic dimensions the integrative model may help to investigate the relation of subcomponents of empathy and their neural underpinnings more systematically.

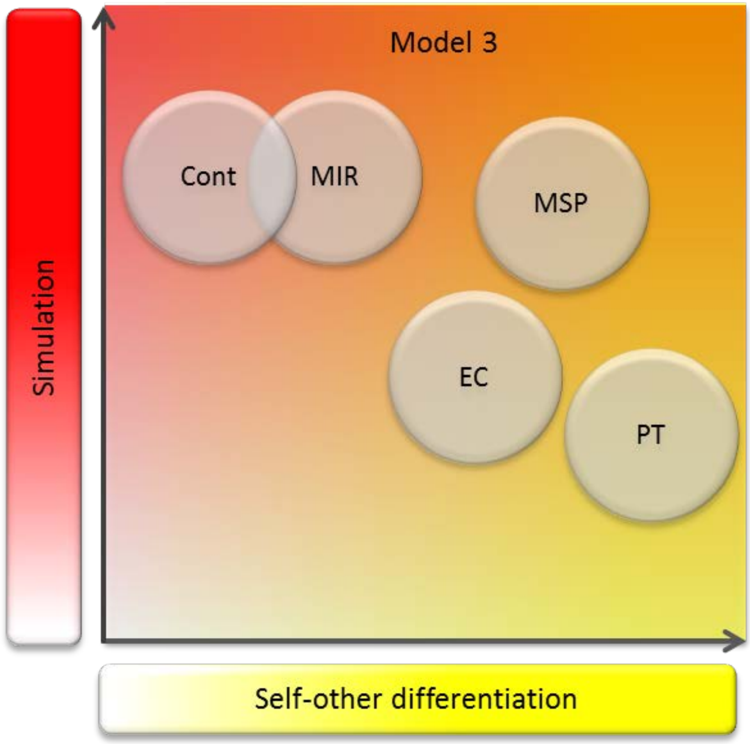

Figure 14. A new integrative model (model 3).
Abbreviations: Cont = emotion contagion, MIR = emotion mirroring, MSP = mental state perception, EC = empathic concern, PT = perspective taking.

Before evidence for the integrative model is reviewed, the potential cognitive and neural processes are described further that may underlie the integrative model. This model suggests that mirroring processes provide rapid and intuitive bottom-up input by simulating observed or imagined actions, gestures or facial expressions. This information is then fed into the ToM-network where an identified action or gesture can be reflected upon more consciously. On the other hand, top-down modulation of the MNS by the ToM network is required for self-other differentiation to ascribe a representation held in the MNS to either the self or the other. Only this top down modulation therefore allows the subject to decide whether she is experiencing an emotion herself or shares an emotion with another subject. In addition, top down modulation of the simulation process would allow adapting to different context, e.g., more simulation for a human than a robot and for a likable person than for a stranger. Taken together, the integrative model suggests a dynamic interplay of bottom up simulation and top down self-other distinction processes and an interplay between both networks. While others have suggested an interplay between both networks, those other models usually focus only on one direction, i.e., bottom up or top down processes, while neglecting the respective other (Keysers & Gazzola, 2007; Shamay-Tsoory, 2011a; Uddin, Iacoboni, Lange, & Keenan, 2007; Zaki & Ochsner, 2009).

One strong argument that keeps the controversy between model 1 and 2 alive is that the MNS and ToM-network, although serving related functions, are dissociable, considering that the brain regions making up the two systems have been shown to be almost completely non-overlapping and rarely engaged simultaneously (for a meta-analysis, see Van Overwalle & Baetens, 2009). However, as Zaki & Ochsner (2011, p.171) put it "the fact that neural systems can be dissociated does not imply that they are necessarily or even usually dissociated during social inferences, especially those based on the kinds of complex social information that we encounter in everyday situations". Indeed, when using more naturalistic stimuli, the MNS and the ToM network were shown to be concurrently engaged, speaking for the dynamic interplay set forth in model 3 (Brass, Schmitt, Spengler, & Gergely, 2007; de Lange, Spronk, Willems, Toni, & Bekkering, 2008; Wolf, Dziobek, & Heekeren, 2010). The controversy might thus at least partly be an artifact of research culture, where each researcher focuses on a certain brain area or system while neglecting others (Zaki & Ochsner, 2011). Another argument for the integrative model is that studies that have found mirroring processes to be engaged have focused more on simulation-intensive, embodied empathic functions, such as empathy for pain while studies that reported the ToM-network to play a crucial role have used paradigms requiring self-other distinction such as false stories and visual perspective taking (e.g., Santiesteban, White, et al., 2012; Singer et al., 2004). A third argument in support of the integrative model is that a vast amount of research shows that imitation is indeed modulated rather than being an on-off function: imitation is higher in social compared to non-social settings, when the other person is perceived as likable or when the affiliation goal is high (Chartrand & Lakin, 2013).

With respect to autism, the integrative model together with the results of part II of this dissertation suggests that the interplay between the mirroring areas and the ToM-network is disrupted rather than either system per se. This could reconcile the many conflicting findings from previous literature. For instance, the integrative model can explain why automatic imitation is largely intact or sometimes even enhanced in individuals with ASD, while more complex explicit imitation processes during social interactions, that potentially rely more on a dynamic modulation of imitative functions, have consistently been shown to be impaired (Bird et al., 2007; Hamilton, Brindley, & Frith, 2007; Southgate & Hamilton, 2008; Justin H G Williams et al., 2004). In addition, the integrative model can explain why aberrant activation of both networks have been found - albeit inconsistently - to be related to the social deficits in ASD (Castelli, Frith, Happé, & Frith, 2002; Dapretto et al., 2006; Greimel et al., 2010; Kana, Keller, Cherkassky, Minshew, & Just, 2006; Justin H G Williams et al., 2006). Future research should focus on systematically manipulating each dimension of the integrative model to understand the interplay of both networks in ASD. Indeed, a behavioral study testing the modulation of automatic imitation through social priming words found less such modulation in individuals with ASD compared to neurotypicals (Cook & Bird, 2012). In addition, as reviewed in study 3 (section 3.1), aberrant fronto-parietal connectivity seemed to be among the most robust results from recent neuroimaging studies.

Taken together, by suggesting a dynamic interplay between brain networks supporting simulation and self-other differentiation, the new integrative model can help to reconcile not only the findings provided by this study but also from previous research. By allowing to categorize subcomponents of empathy according to the degree they engage either function, future research may be stimulated to devise more specific paradigms to relate empathic functions to neural activity and draw the empathy profile of autism.

4.3.2 CLINICAL APPLICATIONS

By showing that an imitation/synchronization based dance movement intervention was efficient at fostering cognitive empathy in individuals with ASD, this dissertation provides evidence for a clinical application of the link between imitation/synchronization and empathy. It thereby builds on a long tradition in dance movement therapy of using imitation and interpersonal synchronization to target social functions (Sandel, 1952). While dance/movement therapists have used mirroring in movement for decades to build a relationship and enhance emotional understanding between the therapist and the neurotypical or autistic client, evidence has so far only come from a hand full of case reports (e.g., Archambeau & Szymanski, 1977; Samaritter & Payne, 2013; Scharoun, Reinders, Bryden, & Fletcher, 2014). A recent 7-week intervention study focusing on mirroring in movement showed improved self-reported social skills in young adults with autism (Koch, Mehl, Sobanski, Sieber, & Fuchs, 2014), added some empirical evidence. Thus, this dissertation underpins the foundation of this clinical practice by the most rigid clinical trial that has been conducted so far, together with a more thorough investigation of the underlying mechanisms.

Having shown some evidence for the efficacy of this approach, one might speculate on its potential for a broader application. Further effort to follow up on this approach should take into account whether it can be implemented in settings other than dance/movement interventions and in other patient groups than those with ASD. However, it needs to be born in mind that replication of the application within dance/movement therapy and ASD is needed before further steps are warranted.

Despite the insights gained from this dissertation, its clinical scope would be limited if SI-DMI and other applications of the synchrony-empathy link were applicable to ASD only as prevalence rates are low (7.6 in 1000 worldwide, Baxter et al., 2014), compared to other psychological disorders such as depression (6.6 - 21% life time prevalence in high income countries, Kessler & Bromet, 2013) and anxiety (10.4% current prevalence in Euro/Anglo cultures Baxter, Scott, Vos, & Whiteford, 2013). However, deficits in social functioning are not unique for ASD but have been reported for other psychiatric disorders such as mood disorders, anxiety disorders, and schizophrenia and have been suggested to be a general marker of psychiatric disorders (Derntl & Habel, 2011; Kennedy & Adolphs, 2012). Interestingly, more recent research identified deficits in interpersonal synchronization in other disorders associated with deficits in social cognition. Using a task in which participants swing hand-held pendulums in dyads, patients with schizophrenia were impaired in intentional motor coordination but not unintentional motor coordination (Varlet et al., 2012). Unaffected relatives of schizophrenia patients showed the same pattern of results indicating that social motor coordination might serve as an endophenotype of the disorder (Del-Monte et al., 2013). Using the same paradigm, it was shown that individuals with social anxiety disorder showed specific impairments when leading the coordination in the intentional condition (Varlet et al., 2014). Taken together, it seems warranted to investigate the efficacy of SI-DMI in mitigating deficits in social cognition in disorders other than ASD.

One argument speaking against the transfer of SI-DMI to other disorders might be that self-other merging through simulation might be detrimental for some disorders. Patients with schizophrenia for example may experience thought insertion or delusion of control which have been explained as a breakdown of the sense of agency (Blakemore, Wolpert, & Frith, 2002; Frith & Done, 1988). Self-other merging through simulation might aggravate the loss of agency by weakening the experienced boundaries between self and other. More generally, mere simulation when facing another person in distress without ascribing the source of that emotion to the other (self-other distinction) may lead to increased personal distress, i.e., experiencing the observed emotion as one's own (Singer & Lamm, 2009). This was also reflected in study 1 of this dissertation showing an association of trait emotion mirroring and personal distress and emotional instability (neuroticism). Being overly affected by mood changes of others might be particularly detrimental for individuals with affective disorders such as depression and bipolar disorder and disorders involving emotion regulation impairments such as bipolar personality disorder. Thus, although SI-DMI already includes tasks focusing on self-other differentiation as a foundation of reciprocity and dialogue in movement, fostering self-other distinction in addition to simulation might be particularly important when adapting SI-DMI to other populations. In sum, given the relevance of social-cognitive deficits for the outcome of several psychiatric disorders and subjective wellbeing (Couture, Penn, & Roberts, 2006), future studies exploring the benefit of SI-DMI for other populations seems warranted.

With respect to the setting, individual psychotherapy might use the insights from this dissertation to foster the relationship building process in particular at the beginning of a therapeutic process for individuals with ASD but also other disorders. For instance, the first 5 sessions might start with a short walk with or without talking during which synchronous movement such as lock step and synchronous arm swings are encouraged or brought about by the therapist.

A more speculative approach would be to transfer the approach to eHealth interventions. eHealth interventions i.e. in tools and treatments, that are transformed for delivery via Internet or mobile platforms are increasingly important instruments in the toolkit of public health professionals and researchers and have been used effectively, e.g., to help people quit smoking, lose weight, and improve mental health (for an overview, cf. Eysenbach, 2011). One branch of this fast growing field consists of so-called “serious games” aiming to integrate playing games, and learning or training for serious purposes like education, and health (Wiemeyer & Kliem, 2011). Interestingly, many existing commercial computer games for pure entertainment already involve interpersonal synchronization so that transferring these into serious games might be particularly feasible. For example, the computer game "SingStar Ultimate Party" for PlayStation (Sony Computer Entertainment Europe, 2014), involves dubbing well-known songs to music, in a karaoke-like fashion. Importantly, the game console allows for two participants to sing simultaneously, thereby allowing for synchrony to occur. The effect of synchrony could be enhanced by replacing the singing with a joint drumming task with virtual and real players with and without music to increasingly complex rhythms. Another candidate for use as a serious game might be the so-called "DanceDanceRevolution", which was introduced 1998 by Konami, Japan as a coin-operated entertainment machine. In this game, participants earn points by following whole body movements indicated through arrows and symbols on screen while avatars perform the same movements synchronously in a mirrored fashion (Figure 15). The movements are tracked by the gaming console, and constant feedback is given. Today, technically up-to-date versions of this game have been released across the globe on various platforms including Nintendo Wii (Nintendo, 2010), and tournaments are held worldwide (e.g., Konami Digital Entertainment, 2013), testifying the great success and popularity of this game. Interestingly, games similar to DanceDanceRevolution are already being used in the public health sector supporting fitness programs in schools in the UK, especially for those not normally inclined towards exercise (Quick Controls Ltd, n.d.).

Figure 15. Screenshot DanceDanceRevolution Wii (Nintendo, 2014).

By playing DanceDanceRevolution, individuals can experience being in synchrony with an avatar in a save setting, starting with slow and easy movements and gradually increasing complexity. The need for structure and sameness common in individuals with ASD can be easily accommodated in this framework. Importantly, DanceDanceRevolution Wii (Nintendo, 2010) now offers a multi-player mode in which up to four players can perform the same choreography together, thus allowing for synchrony between multiple players to occur. Adaptations of this commercial games for use in serious games could include more basic levels with simpler movement sequences to accommodate clumsiness typically associated with ASD (Fournier, Hass, Naik, Lodha, & Cauraugh, 2010). Another idea for adaptation would be to remove the symbols and arrows so that players rely on imitating the movements of the avatar on screen since study 2 showed that it is *mutual* synchronization in particular that is associated to trait empathy. One might also want to think about ways to include more reciprocal elements of movement and exercises of self-other distinction in movement since studies 4 and 6 suggest that those are important additional functions that underlie empathy. Thus, although a serious game may not be able to substitute the therapeutic effect of a more holistic dance/movement therapy, an attempt seems warranted to include interpersonal synchronization and imitation in serious games aimed at fostering empathic functions.

To conclude, this dissertation provides empirical evidence for a long tradition of using mirroring in movement to create rapport in dance/movement therapy. While this approach needs replication before it can be implemented in clinical practice, transferal to other therapeutic settings and clinical populations seems warranted.

4.3.3 THE BENEFITS OF DISSECTING EMPATHY

One major drawback of studying social cognition in general and empathy in particular is the complexity of the constructs investigated. The findings provided in this dissertation mitigate this issue by providing a new integrative model that structures subcomponents of empathy based on 2 more basic functions (simulation and self/other distinction) and a new multidimensional empathy questionnaire designed to measure those subcomponents separately (CEEQ, study 1, section 1.1).

By capturing subcomponents of empathy in line with the integrative model (model 3), the CEEQ could facilitate the integration of research results across different disciplines. In social neuroscience for example, correlational analyses of brain activity and subjective trait measures of empathy are used to elucidate the function of the observed activation (e.g., Braadbaart, de Grauw, Perrett, Waiter, & Williams, 2013; Lamm, Nusbaum, Meltzoff, & Decety, 2007; Singer et al., 2004). However, it has been shown that subcomponents of empathy vary in the degree to which they involve dissociable brain networks (e.g., Shamay-Tsoory, 2011b), so that data from questionnaires that measure empathy as one compound construct such as the Empathy Quotient (Baron-Cohen & Wheelwright, 2004) don't actually map onto a specific neural correlate. Thus, a self-measure allowing to measure subcomponents like the CEEQ might be better suited to inform results from neuroscientific studies. Indeed, most empathy researchers apply the multidimensional IRI (Davis, 1983) to inform their fMRI data, but mostly failed to observe a correlation between subscales of the IRI and hemodynamic activation (for a selective review, cf. Decety, 2011). This might be due at least partly to the fact that the IRI in contrast to the CEEQ is rather outdated and thus does not reflect the constructs currently investigated in social neuroscience very well. Thus, the CEEQ might prove particularly useful for future neuroscience studies.

Other fields that will profit from an up-to-date assessment and the integrative model of empathy in terms of different subcomponents are those concerned with the evolutionary origins and ontogeny of empathy (e.g., Preston & de Waal, 2002). When assessing empathy in infants or non-human animals, precursors of empathy need to be mapped onto subcomponents of the fully developed mature construct. It is therefore important to be able to measure the mature equivalents of those precursors specifically in adults. For example, emotional contagion or "primitive empathy", which can also be observed in infants and monkeys (Hatfield, Cacioppo, & Rapson, 1993; Preston & de Waal, 2002), might be an evolutionary and ontogenetic precursor of emotion mirroring. It is therefore interesting to measure those functions in adults. Interestingly, study 1 showed that emotional contagion in adults seems indeed to be specifically related to emotion mirroring (Savage, Teague, Koehne, Borod, & Dziobek, 2014). Previous self-rating scales did not include this subcomponent of empathy (Davis, 1983). Thus, by providing a tool that allows the separate measurement of subcomponents of empathy based on an integrative model relating these subcomponents to each other and to a neural correlate, this dissertation might add to our understanding how empathic subcomponents develop and build on each other evolutionary and ontogenetically.

Thus, although broader constructs of social cognition such as empathy might resonate well with lay knowledge and common sense, they might be of limited scientific utility, so that an up-to-date model together with an adequate self-report measure is important to advance research in the fields outlined above. The CEEQ does not, however, claim to be conclusive with respect to the number of subcomponents of empathy. For instance, kinesthetic empathy, for which a separate scale was developed and evaluated in the context of study 2 (section 2.2.) could be included in a broader questionnaire. Future factor analytical studies in larger samples are needed to show which subcomponents shared enough variance to warrant subsuming these scales under one broader factor empathy. Providing measurement tools for different levels of abstraction will help understanding empathy in all its complexity.

Since deficits in interpersonal synchronization have been identified across different disorders associated with deficits in social cognition besides ASD, such as schizophrenia and social anxiety disorder (Del-Monte et al., 2013; Varlet et al., 2012, 2014) interpersonal synchronization might be a candidate construct for the Research Domain Criteria (RDoC) project of the American National Institute of Mental Health (NIMH). This project's goal is to develop new ways of classifying mental disorders based on behavioral dimensions and neurobiological measures (National Institute of Mental Health, n.d.-a). To this end, a matrix was established listing constructs such as, e.g., attention, reward evaluation and arousal, and operationalizations of these constructs on different levels of analysis from genetics to behavior (National Institute of Mental Health, n.d.-b). Rather than focusing on one specific clinical diagnosis and investigating underlying mechanisms, this project suggests to start with dysfunctions of those basic constructs as a way to understand symptomatology based on a specific mechanism across multiple disorders. Interpersonal synchronization, or, if taken together with mimicry, interpersonal coordination, might qualify for a construct worth investigating across different clinical diagnosis involving social deficits. NIMH has proposed two criteria that have to be met in order to include a construct in the matrix: In addition to sufficient data to support the construct as a valid functional dimension of behavior or cognition, there have to be data specifying a neural circuit or system that accounts for a preponderant amount of the variance in implementing the particular function (National Institute of Mental Health, n.d.-b). While there is substantial evidence validating the construct on the behavioral level (Chartrand & Lakin, 2013), and a very good understanding of the neural implementation of imitation processes (Rizzolatti & Sinigaglia, 2010), what would be needed most are studies on the neural correlates of interpersonal synchronization, although first efforts have been made into this direction (Fairhurst et al., 2013; Yun et al., 2012). One advantage of using interpersonal synchronization as a proxy for social processes is that somatosensory interpersonal synchronization, i.e., synchronization of a person with an external stimulus such as a metronome, is very well understood through basic research and computational modeling (Repp & Keller, 2008). The construct of interpersonal synchronization/mimicry could for instance be listed as subconstruct under the RDoc constructs "Social Communication" or "Perception and Understanding of Others".

4.3.4 INSIGHTS FOR INTERDISCIPLINARY COLLABORATIONS

In part I of this dissertation, through the investigation of empathy in experts of interpersonal synchronization (Capoeira players and Tango dancers) and non-experts (Breakdancers and Salsa dancers) using the newly developed CEEQ, it was possible to gain support for an association of synchronization and higher-order empathy components (cognitive and emotional empathy). Specifically, an increase in kinesthetic empathy in expert synchronization groups was demonstrated, which was associated with cognitive and emotional empathy and might thus represent a precursor of these components. This notion was corroborated through the findings of a highly controlled experimental study in part II.

The association of synchronization and empathy might also inform research from other disciplines interested in social phenomena, such as anthropology, sociology, and history. Indeed, interpersonal synchronization and its role in society were attended to in these fields from the beginning of the last century, when scholars began to ask for the function of group rituals. Such ecstatic group rituals were a regular and nearly universal practice among tribal societies at the time of European contact and involved among other features drumming, chanting, and dancing to the point of exhaustion (Ehrenreich, 2006). Researchers across fields converged on the notion that these rituals served to enhance group cohesion: The sociologist Émile Durkheim (1965) coined the term "collective effervescence" to refer to the role of ecstatic group rituals in the long-term maintenance of a cohesive group, and anthropologist Victor Turner (1995/1969) used the term *communitas* to describe the state of a society during ritual, in which structure is temporarily abolished and the relationship among people is affirmed. Historian William H. McNeill (1995) and anthropologist Barbara Ehrenreich (2006) both maintain that synchronous movement (e.g. rhythmic drumming and moving together in time) is the most widespread and powerful biological cooperation-enhancing mechanism. For instance, McNeill (1995, p.4-5) suggests that throughout recorded history, moving and singing together made collective tasks from simple field work to building the pyramids of Egypt more efficient, and village dancing helped to smooth out frictions and consolidate fellow-feeling among participants.

Importantly, while these essays on group-cohesion assess the effects of synchronization evolving at the group level, the results of this dissertation add to this knowledge by elucidating the effects of synchronization on the individual level. In doing so, they allow to speculate on the mechanism behind "collective effervescence" and *communitas*. For instance this dissertation suggests that synchronous movements may lead to shared emotions (emotional empathy) which might be the first step towards the feeling of oneness during *communitas.* One might even go a step further and assume that *communitas* relies on simulation processes on the neural level as they have been shown for dyads playing the guitar (Lindenberger et al., 2009). It would be interesting for future research to show that the same mechanisms are at work on the group level. On a similar note, Dezecache et al. (2013) provided evidence that emotional homogeneity within a crowd might result from a cascade of local emotional transmissions where the perception of another's emotional expression produces, in the observer's face and body, sufficient information to allow for the transmission of the emotion to a third party. Thus by investigating the role of synchrony in empathy on the individual level, this dissertation might add to shed light on processes investigated in disciplines focusing on the group level.

The importance of assessing effects of interpersonal synchrony at the individual level as was the aim of this dissertation becomes particularly clear when turning towards more recent work from social sciences that draw conclusions from their work for public policy. It has been suggested that in today's industrialized societies, the magic of interpersonal synchrony is still at work, resulting in modern versions of ecstatic communal rituals such as rave dances to beat-heavy, repetitive music (Olaveson, 2004). Other examples of synchrony in modern society might be the collective singing and waving of football crowds and simultaneous moving and breathing during yoga classes. The so-called "hive hypothesis" takes this notion one step further by claiming that "people need to lose themselves occasionally by becoming part of an emergent social organism in order to reach the highest level of human flourishing" (Haidt, Seder, & Kesebir, 2008). Persuaded by the benefits of synchronous movement for society and the individual, the authors suggest to change public policies to increase the availability of music, dance, and street festivals, e.g., by making it easier to block off a street or changing related tax regulations, and discuss introducing synchronous movement in corporations similar to the collective morning or midday exercises of some Japanese companies. Of note, those suggestions for public policy were made in a law journal and thus directed towards those in charge of implementing social transitions.

Before such implications are put into practice, however, potential detrimental effects of synchronous movement should be assessed in greater detail. While this dissertation focuses on the prosocial aspects of interpersonal synchrony, Wiltermuth (2012a, 2012b) showed that synchronous movement leads to higher compliance with requests to aggress and destructive obedience. In his experiment, participants instructed to follow a leader while walking in-step with him were more willing to kill sow bugs at the leader's request in an ostensibly different experiment than were participants in other conditions (Wiltermuth, 2012b). In another experiment, participants who acted in synchrony with a confederate (moving plastic cups from hand to hand in time with music) were more likely than were participants in the asynchronous condition to comply with the confederates request to administer a noise blast to another group of participants (Wiltermuth, 2012a). In both experiments, increased feelings of connection/closeness with the confederate mediated the relationship between synchrony and heightened compliance with the request to engage in aggressive behavior. These findings imply particular caution with led synchrony, while this risk might be smaller in occasions where synchrony evolves from within the group without one particular leader such as during informal dancing. When investigating these kinds of mechanisms, cognitive and emotional empathy are candidate constructs mediating the effect of synchrony onto more distal effects. It would be interesting for future studies to investigate which parameters predict a positive or negative social outcome of synchronization to further inform implications for public policy.

Taken together, the studies presented in this dissertation bear several strengths. Together, they target the question of the association between interpersonal synchronization/imitation and empathy functions from various angles, by investigating populations with specific strengths and specific deficits in these fields, combining a ecologically valid field study with highly controlled experimental approaches, in addition to implementing cross-sectional and longitudinal research designs. They further represent the product of close interdisciplinary research, showing how concepts and methods of various fields can be combined to enhance our understanding of interpersonal processes. At the same time, the studies add to the embodiment approach, which holds that all mental processes are deeply rooted in bodily processes (Glenberg, 2010). Most importantly though, the findings presented here might point towards a route to enhance sharing and understanding the thoughts and emotions of each other, which might not only mitigate social problems and sorrows of those affected with ASD, but prove beneficial for everyone living in today's increasingly socially demanding world.

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APPENDIX

LIST OF ABBREVIATIONS

ADI-R	Autism Diagnostic Interview – Revised
ADOS	Autism Diagnostic Observation Schedule
AI	Automatic Imitation
AQ	Autism Spectrum Quotient
ASD	Autism Spectrum Disorder
ASDI	Asperger Syndrome and High-Functioning Autism Diagnostic Interview
ASIM	Assessment of Spontaneous Interaction in Movement
BDI-II	Beck Depression Inventory II
BMT	Broken Mirror Theory
BSI	Brief Symptom Inventory
CEEQ	Cognitive and emotional empathy questionnaire
CI	Confidence Interval
CMI	Control Movement Intervention
CNV	Copy number variations
Cont	Emotion Contagion
DALY	Disability Adjusted Life-Years
DGPs	German Society for Psychology
DSM	Diagnostic and Statistical Manual of Mental Disorders
DTI	Diffusions-Tensor-Bildgebung
EC	Empathic Concern
EC	Efector Compatibility (in study 4)
ECS	Emotional Contagion Scale
EEG	Electroencephalogram
EF	Exekutivfunktionen
EFT	Embedded Figures Test
EPQ-R	Eysenck Personality Questionnaire - Revised
EQ	Empathy Quotient
ERQ	Emotion Regulation Questionnaire
FG	Fusiformer Gyrus
fMRI	functional magnetic resonance imaging
FS	Fantasy
IBI	inter.beat interval
ICC	Interclass Correlation Coefficient
ICD-10	International Classification of Drseases, 10th ed.
IFG	Inferiorer Frontaler Gyrus
IOI	Inter Onset Inteval
IRI	Interpersonal Reactivity Index

ITT	Intention-To-Treat
KinEmp	Kinesthetic Empathy
LPS	Leistungsprüfsystem
MASC	Movie for the assessment of social cognition
MET	Multifaceted Empathy Test
MIR	Emotion Mirroring
MNS	Mirror Neuron System
mPFC	Medialer Präfrontaler Kortex
MRT	Magnetresonanztomographie
MSP	Mental State Perception
MT	Mosaiktest
NT	Neurotypical
NYEB	New York Emotion Battery
PCA	Principle Component Analysis
PD	Personal Distress
PDD	Pervasive Developmental Disorder
PDD - NOS	Pervasive Developmental Disorder - Not Otherwise Specified
PET	Positon Emission Tomographie
PT	Perspective Taking
RCT	Randomized Controlled Trial
RFFT	Ruff Figural Fluency Test
RME	Reading the Mind in the Eyes Task
RT	Reaction Time
SC	Spatial Compatibility
SI-DMI	Imitation and Synchronization-based Dance/Movement Intervention
SNS	Spiegelneuronensystem
STS	Superiorer Temporaler Sulcus
TAS	Toronto Alexithymia Scale
ToM	Theory of Mind
TP	Temporalpol
TPJ	Temoroparietale Übergangsregion
VP	Virtual Partner
WST	Wortschatztest
YLL	Years lived with disability
ZK	Zentrale Kohärenz

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LEBENSLAUF

Der Lebenslauf ist in der Online-Version aus Gründen des Datenschutzes nicht enthalten.

EIDESSTATTLICHE ERKLÄRUNG

Hiermit erkläre ich an Eides statt,

- dass ich die vorliegende Arbeit selbstständig und ohne unerlaubte Hilfe verfasst habe,
- dass ich mich nicht bereits anderwärts um einen Doktorgrad beworben habe und keinen Doktorgrad in dem Promotionsfach Psychologie besitze und
- dass ich die zugrunde liegende Promotionsordnung vom 02.12.2008 kenne.

Ort/Datum

Svenja Maren Köhne