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Interacting with others: the role of temporal contingency and motor interpersonal synchrony in Autism Spectrum Disorder and in Typical Development

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Introduction

This work focuses on the theme of Interpersonal Synchrony (IS), which is a spontaneous rhythmic and temporal coordination of actions, emotions, thoughts, behavioural, neurological, and physiological process that occurs between two or more people. All the levels of IS appears to have a great impact on the facilitation of social interaction in the typical population (TD), by promoting affiliative and prosocial behaviours throughout the entire life. The first chapter will be dedicated to the introduction of this topic.

The second chapter will be focusing on the Interpersonal Synchronization in the Autistic Spectrum Disorder (ASD): individuals in the spectrum show decreased or absent ability to align with others, as cascading effects, difficulties in the social and communicational areas. To the purpose of this work, there will be a focus on Motor Interpersonal Synchrony. Furthermore, two components of the Interpersonal Synchrony will be presented: the temporal contingency (responsiveness) and the engagement (communicativeness) of the stimuli.

The Motor Interpersonal Synchrony will be investigated throughout meta-analysis in the third chapter: eleven studies involving dyads of ASD and TD participants are analyzed. The aim of the work is to provide an understanding of the Motor IS deficits in the ASD population by answering to the question: "*Do ASD (compared to TD) individuals manifest reduced interpersonal motor synchrony during social exchanges?*".

The fourth chapter will be dedicated to understanding whether and how temporal contingency and the communicativeness of the stimuli could influence the willingness to interact with them or the preference for one stimulus compared to another. An experimental paradigm was designed to this purpose and the results are presented.

Finally, the last chapter will be dedicated to the discussion of the findings, of the limitation of the two studies presented and of the possible future research that could be useful to provide a clearer understanding of the Interpersonal Synchrony and its components. Moreover, possible implications for the clinical work will be discussed.

Chapter I

INTERPERSONAL SYNCHRONY

1.1 What is Interpersonal Synchrony

Interpersonal coordination is a broad term that includes the concepts of interpersonal synchrony and of behavioural mimicry and describes the interdependence that occur between two or more people (Mayo & Gordon, 2020). Behavioural mimicry is used to describe the behavioural interdependence when two people behave in the same way for a short period of time: in other words, mimicry is the spontaneous and unconscious coping of actions during a social interaction and can also be referred to as imitation (Klerk et al., 2018; Chartrand & Lakin, 2013). Interpersonal synchrony (IS) or entrainment, instead, is defined as the spontaneous rhythmic and temporal coordination of actions, emotions, thoughts, and physiological process between two or more people (Mayo & Gordon, 2020; Ackerman & Bargh, 2010).

Interpersonal synchrony mechanisms have been studied in a variety of contexts and from different points of view, therefore different types of IS can be described (McNaughton & Redcay, 2020).Three main levels of synchrony have been distinguished: physiological, neural and behavioural.

The synchronization can be observed through physiological measures, such as the heart rate and the heart rate variability, the blood pressure, the electrodermal activity, and the cortisol levels (Mayo & Gordon, 2020). Physiological synchrony has included any interdependent or associated activity that has been identified, through appropriate measures, in the physiological process of two or more individuals (Palumbo et al., 2016). It has been observed that interacting partners tend to show synchronized sympathetic and parasympathetic nervous system activation and adrenocortical activity, meaning that their physiological status is aligned due to the ongoing encounter (Palumbo et al., 2016). For example, a study by Lunkenheimer and colleagues (2015) investigated the alignment of the respiratory sinus arrhythmia (RSA) in mothers-preschoolers child dyads. They involved the dyads in different tasks (free play, clean up task and puzzle task) and measured the RSA by using an electrocardiogram (ECG), to see if there was a co-regulation in the physiological index. The data provided evidence for a mother-child

synchronization in this parasympathetic process during their interaction (Lunkenheimer et al.,2015).

The synchronization happens also at a neural level: MRI and MEG studies have identified an alignment of the brain activity between interacting individuals (McNaughton & Redcay, 2020). The research on this field is growing thanks to the spreading of the hyper-scanning technique, which allow to record simultaneously the activity of two or more brain, usually by electroencephalogram (EEG) or near-infrared spectrometry (NIRS). (Mayo & Gordon, 2020). Being able to study the inter-brain synchronization means to detect the temporal alignment of neural oscillation of the interacting partners. A dual-EEG study measured the neural entrainment between two people during non-verbal interaction, indeed they had two perform spontaneous hands movements: alpha and mu brain waves appeared to be synchronized in the right centroparietal region, showing the involvement of that area in the neural entrainment (Dumas et al., 2010).

Finally, behavioural synchrony refers to the alignment of behaviour that takes place during interactions. When the interpersonal synchrony occurs between two people, the dyadic entrainment is achieved within the couple, by interacting, speaking, or showing affection (Markova et al., 2019). Studies on dyads involved parent-child couples, but also peers couple of typically-atypically developing individuals to see how the synchronization might change depending on the individual characteristics of interacting partners. Triadic interactions usually involve two people and an external object or element, such as music or toys, which trigger the joint attention and thus the synchronization. Otherwise, triads can be represented by three people, for example mother-father-child, all being aligned (Markova et al., 2019). Finally, Behavioural Interpersonal Synchrony consider both the verbal and non-verbal level.

The verbal alignment is called conversational synchrony: the entrainment can be found in the linguistic elements and conceptual aspects that occur over the course of a conversation (Louwerse et al., 2012). The linguistic synchronization can be observed at the lexical, semantic, syntactic, phonological, and phonetic level and it takes place automatically during a dialogue (Louwerse et al., 2012; McNaughton & Redcay, 2020).

1.1.1 Motor Interpersonal synchrony

The non-verbal entrainment, instead, focuses on the body movements and therefore it is called motor interpersonal synchrony. It appears to be the most studied type of entrainment since it is easier to investigate in many different contexts and it might result easier to be observed. McNaughton and Redcay (2020) defined it as the time- and form-aligned behaviours that occurs in social interaction and that naturally emerges in a variety of social contexts. It has been investigated through a variety of experiments, involving many different tasks and condition: for example, it has been studied within the interaction between two or three people, the whole-body motion or just some pre-defined region of interest, adults and or children interacting with peers, with younger or older people. An example of task used to study motor interpersonal synchrony is the rocking chair paradigm: two people sitting on a rocking chair while interacting tend to rock following the same rhythm. Such paradigm was tested with dyads made by an adult and a child reading a book together: the outcome, as predicted, was that people started moving back and forth their chair at the same rhythm (Marsh et al., 2013). Another example is the swinging pendulum paradigm, in which two people sitting across from each other and holding a pendulum in their hand, tend to coordinate the pendulum movement and to act in-sync (Fitzpatrick et al., 2017).

The coordination of the movement, and therefore the synchronization includes both the in-phase and anti-phase movements. This is one of the aspects that distinguish the behavioural mimicry form the synchronization: in mimicry two individuals perform the same action at the same time and include a discrete bodily movement (Miles et al., 2009). Interpersonal synchrony refers to a more continuous and complex sequence of action, in which behaviours can be either complementary or similar. This means that it can be observed an in-phase coordination (symmetric coordination), in which people's movements are at equivalent point of the movement cycle, and anti-phase coordination, in which actions are at the opposite point of the cycle (Miles et al., 2009). Both type of coordination reflects the interpersonal coordination between two or more people interacting.

Another distinction to be made regarding the timing of synchrony. Concurrent IS includes joint actions and attention, mutual gaze, and mirroring. Sebanz et al. (2006) defined joint action as "*any form of social interaction whereby two or more individuals*

coordinate their actions in space and time to bring about a change in the environment": the attention of two or more people interacting needs to share a common ground and to be concurrent to perform successfully. IS, indeed, is also referred to as concurrent co-variation (Mayo & Gordon, 2020). Interpersonal synchrony can also be sequential, as it is in turn taking and reciprocity. Turn taking refers to all the alternations that take place within an interaction, including speaking, being in silence, moving or staying still. For example, during a conversation, turn taking is organized in an alternation of speaking and silence of the two interlocutors, in which people need to understand the points of interruption, when to start or stop speaking, and to follow the rhythm of the conversation. In other words, people need to be coordinated and thus synchronized in a sequential mode (Wilson & Wilson, 2005). Some authors also include the imitation in the definition of sequential IS (Wilson & Wilson, 2005), however the literature is ambiguous since it is used as a synonym to talk about mimicry (Klerk et al., 2018; Chartrand & Lakin, 2013). In this perspective, interpersonal synchrony is something more complex than just a copy of someone else action. For the purpose of the present work, imitation will be considered as a synonym of mimicry and not as part of the interpersonal synchrony.

Finally, IS can be distinguished between spontaneous and induced (or active and passive IS), especially in experimental contexts. Studies that investigate the spontaneous interpersonal synchrony measure how two people behave and become synchronized without receiving any instruction of synchronizing. The measures have been taken during a singing, dancing, or drumming task or by tracking the eye movements or the body posture changes (Marsh et al., 2013; Trevisan et al., 2020; Hu et al., 2022). In induced IS experiments it was explicitly requested to cooperate during the assignment, for example with instructions such as "Now, let's try it a few times together" or to "create synchronized and interesting motions" (Fitzpatrick et al., 2013; Brezis et al., 2017). The most popular tasks involve either walking, stepping, tapping finger together or to follow the same stimulus to move in synchrony (Hu et al., 2022). Marsh and others (2009) explained that there are circumstances in which individuals are spontaneously pulled into the orbit of others accidental behaviours and movement. On the other side, there are some daily life circumstances in which, due to environmental constrains or personal limitation, interpersonal synchrony and coordinated joint actions are induced (Marsh et al., 2009). Thus, spontaneous and induced interpersonal synchrony are constantly alternated in the daily life.

Even though all those distinctions can be made, Interpersonal Synchrony is a multimodal and complex construct, in which the different types and levels constantly adapt to ongoing interaction.

1.2 The role of Interpersonal Synchrony for social communication

Interpersonal synchrony (IS) raised interest in the research field because it appears to play a crucial role in the communication and cooperation between individuals. It seems to be a mechanism that allows daily activities in which people need to be coordinated, such as parent-child interaction earlier in life, dancing together or applauding at the same pace (Feldman, 2007; Mogan et al., 2017; Hove & Risen, 2009). The development of interpersonal synchrony starts when the baby is still in the womb and keeps going throughout infancy, but those aspects will be addressed in the next paragraph.

It's important to highlight that there is a reciprocal process of influence between individuals during social interplay and that interpersonal synchrony facilitates harmonious and cooperative interaction (Galbusera et al., 2019). All levels of synchrony (physiological, behavioural, and neural IS) and both spontaneous and induced IS appears to have a positive impact on the quality of the social interactions (Chartrand & Lakin, 2013; Brezis et al., 2017).

As mentioned earlier, Interpersonal Synchrony is a key mechanism for an effective communication: when two people talk, it allows the collaborative turn alternation, silence, ecc (Wilson & Wilson, 2005). This implies being able to understand the rhythm of the conversation, but also to anticipate other's behaviour and intention to coordinate movement timing (Hove & Risen, 2009). Indeed, studies on turn taking highlighted the importance of the anticipation for a better comprehension of the ongoing conversation, the preparation of the answer and especially for the alignment in turn switching (Magyari & De Ruiter, 2008). Being coordinated with someone else, and this acting in-synch, require an anticipation of the partner's behaviour. For example, it has been observed that musicians playing together tend to predict what the others will to create a synchronized and performance. Thus, Pecenka and Keller in 2011 proposed a sensorimotor synchronization paradigm involving professional and amateur musicians and non-musicians: they were all previously assessed to see if they fitted in to the high (HP) or in the low (LP) predictive group, through a solo tapping task. Then, experimenter

formed dyads which could be HP-HP, LP-LP or LP-HP and they asked to perform a dyadic tapping task. The outcome showed that the mixed dyads synchronized less compared to the HP-HP couple, but more compared to the LP-LP dyads. The HP-HP couple had the highest synchronization and accuracy level, due to their ability to anticipate the other's action and the upcoming sounds, hence, to coordinate their responses. Therefore, being able to detect the timing and the temporal contingency between events is associated with a higher anticipation capability and a higher interpersonal synchronization (Pecenka & Keller, 2011; Pouw & Holler, 2022). In other words, noticing the temporal contingency between events or behaviours seems to concur in triggering the interpersonal synchrony. Contingency refers to the dynamics and the temporal association between the observed behaviour and one's own behaviour (Brandi et al., 2019). The literature about the contingency effect on interpersonal is very limited and not consistent. Many papers talk about it vaguely, stating that the timing and the temporal contingency could be important for the alignment during the interaction between individual and for the enhancement of the interpersonal entrainment. Unfortunately, there isn't a strong research background that explain in depth the relation between IS and temporal contingency. More research needs to be done to have a broader and clearer view on the matter.

During social exchanges, the reaction latency of a response from a partner can determine the perception of that interaction, by modifying the perceived sense of agency. This term refers to the feeling of being responsible of a change in the environment: the definition can be extended to the social sphere, when an action produces an outcome such as a reaction in another person (Brandi et al., 2019). If the response's contingency is high, meaning that the reaction time and the social response is fast, people will perceive themselves as very much able to produce a reaction. A higher social agency is associated with a higher perception of engagement as a positive factor for the interaction quality, along with a higher probability to elicit responsiveness and a higher perceived social agency in the others as well (Canevello & Crocker, 2010; Brandi et al., 2019)

From the neural perspective, a growing body of evidence shows that IS that can be observed at the brain level, through EEG and NIRS hyper-scanning studies, facilitate communication and affective co-regulation, especially in adults (Markova et al., 2019). A temporo-parietal activation has been found during a task in which an individual feeling

pain were touching hands with a partner. The synchrony in the activity of the two brains was associated to pain alleviation and to a better emotional appraisal (Goldstein et al., 2018). The interpersonal touch and the subsequent interpersonal synchrony perceived, with a feeling of analgesia, might be linked to a sort of blur between the self and the other. This can be seen both at the neural level, with a similar brain activation, but also at the physiological level, with similar pattern of activation and arousal (Goldstein et al., 2018). In other words, the temporal closeness and the contingency of perception, anticipation and action decrease the self-other boundaries (Rennung & Göritz, 2016; Smith, 2008).

Mayo and Gordon in 2020 stated that, both in children and adults, IS increases pro-social behaviours and attitude, perceived social bonding, and improve social cognition. Pro-social behaviours include sharing, helping, and trusting, but also affiliation, conformity, feeling of closeness, empathy, and positive evaluation (Hu et al., 2022). A possible explanation to this pro-social effect could be, as previously mentioned, that interpersonal synchrony promotes an overlapping between the self and the other. Since the movements are contingent and simultaneous, and the synchronization occurs at all levels simultaneously (behavioural, physiological, and neural) the individuals become closer and this interfere in the capability to determine the self-other boundaries (Hu et al., 2022; Hove & Risen, 2009). This leads to a closer relation between people and to a sense of affiliation, and vice versa, the closeness leads to even more interpersonal synchrony (Hove & Risen, 2009). In particular, a series of studies on adults by Hove and Risen (2009) showed that it was the interpersonal motor synchrony (tapping in synchrony with a partner) that contributed to liking and affiliation, rather than a general synchrony with inanimate objects (tapping in synchrony with a metronome). To investigate if being synchronized also influenced children, Cirelli and colleagues in 2014 proposed a study with 14-months-old babies. They wanted to see if and how a motor synchrony task, paired with a musical cue, would enhance the engagement prosocial activities. During the test babies were listening to music and held by and assistant in front of the experimenter; both of them bounced either in-sync or out-of-sync. After that, babies were sitting with the experimenter, who "accidentally" dropped a tool to see the infant's reaction. The results showed that 14-months-old from the in-sync bouncing group were more likely to engage in prosocial behaviours towards the experimenter (Cirelli et al., 2014). Moreover, Rabinowitch and Meltzoff in 2017 tested 4-years-old to understand deeper the IS-prosocial behaviour association. They proposed a synchrony/asynchrony activity, called

swinging treatment (trained musician pushed a swing either in- or out-of-sync), followed by cooperative tasks. Results showed that a 4-years-old couple performed better and finished faster the cooperative task, compared to the asynchronous swinging group. Furthermore, this study provided evidence that synchrony is what enhance cooperation, and not just a general rhythmical experience, otherwise no differences would have been found. This means that even children are influenced by the IS, thus they are better to coordinate their behaviour with others and are keener to show pro-social behaviours (Rabinowitch & Meltzoff, 2017).
Finally, To extend the knowledge about affiliation and IS to the conflict's domain, Paxton and Dale (2013) examined dyadic interaction during an argument to investigate the changes in body movements. The results confirmed the previous findings about the link between IS and affiliation. They also found that conflicts decrease and disrupt the affiliation and thus the interpersonal synchrony (Paxton & Dale, 2013).

IS facilitates not only pro social behaviours, social cohesion, and bonding, but also it has a role in the development of self-regulation, empathy, and symbolic skills (Mayo & Gordon, 2020).

Koehne and colleagues (2016) investigated the link between IS and empathy, specifically cognitive empathy, which is the ability to understand other's mental states. Their research aimed to study the perceived interpersonal motor synchrony: people interacted with a pre-programmed computer in a tapping task, having the role of the leader or of the follower and thinking that on the other side of the computer there was another participant. After the task, empathy was assessed. Results showed that a neurotypical group reported more cognitive empathy towards their partner, if they perceived synchrony in the interaction (Koehne et al., 2016). Furthermore, the neural study by Goldstein et al. (2018) on pain alleviation, proposed the idea that interpersonal neural synchrony increases empathic sharing. They found that the observer could show an adequate emotional support, the partner reported lower thresholds of pain and they shared a similar physiological arousal (Goldstein et al., 2018). Those findings are in line with previous research on the positive effects of interpersonal synchrony during social engagement.

Interpersonal synchrony is important also in the process of self-regulation and self-organization of movements and behaviour to interact with others (Galbusera et al.,

2019). During a social interaction, individuals need to respond to their needs, but also to partner's requests. To do so they need to find a balance between those two aspects, which lead to the behavioural regulation in the social environment. According to this point of view, an excess in both the social engagement and in the social isolation could lead to the instability and dysregulation of the self. In this perspective the extreme levels (too high, too low) of interpersonal synchrony could have a negative impact in the self-regulation. To examine in depth this idea, Galbusera and colleagues (2019) proposed a study focused on the impact of IS on the self and on the self-regulation. The study used the Body-Conversation Task (BCT), in which participants had to perform spontaneous and interactive movements to communicate, without talking. The results reported that participants who behaved in-synch during the BCT, showed an increase of positive affect afterwards. On the negative side, participants who showed more IS, reported also more difficulties in self-regulation of affect (Galbusera et al., 2019). Those results point out the problem that if people rely a lot on the social environment to regulate their behaviour and their affect, they will feel less capable of controlling them on their own (Galbusera et al., 2019).

Another study aimed to examine the impact of interpersonal synchrony in the individual perception, and in particular in the level of self-esteem. A paper by Lumsden and colleagues (2014) investigated the impact of synchronous and asynchronous actions on the individual's self-esteem and perception of social connection with their partner. Participants were instructed to either try to coordinate their movement or to try avoiding synchronization with a partner, who was seen from a previously recorded video. A questionnaire was used to assess self-esteem changes before and after the interaction. The result confirmed the authors' hypothesis: moving intentionally in synchrony with a confederate influence the perception of the self, generating a higher self-esteem. In this study the researchers also administrated the Inclusion of Other in the Self Scale (IOS) to investigate the perceived overlap between the self and the other. The result is in line with the literature, showing that moving in synchrony lead to a greater self-other overlap compared to the asynchrony condition (Lumsden et al., 2014).

1.3 The development of Interpersonal Synchrony

Interpersonal Synchrony is fundamental in children's developmental process since it is presents from the very first moments of life and has an important function in the maturation of social communication and social interaction skills.

Feldman in 2007 proposed an overview of developmental aspects of interpersonal synchrony and an accurate timeline of its development, with a focus on the first year of life. Feldman described the synchrony as an intense and playful interaction that builds up familiarity with the rhythm and the behaviour of the others and create a moment of interpersonal exchange. Those interactions early in life play a role in the maturational process of the infant's social and relational skills and provide inputs for the development of self-regulation (Feldman et al., 2003). She also highlighted the importance of timing in the construction of in-sync dyadic relation and of the co-occurrence of behavioural and affective states of parents and children. The temporal and organizational alignment within the parent-child interactions establishes the social bond, co-regulation of arousal and behaviour and constitute the infant's basis to build up empathy, symbol use and the ability to anticipate others' intentions. Research usually focuses on the dyadic interaction between mother and child, with a few papers reporting no significant difference in the temporal contingency and in the interpersonal synchronization in mother-child and father-child dyads (Feldman, 2003).

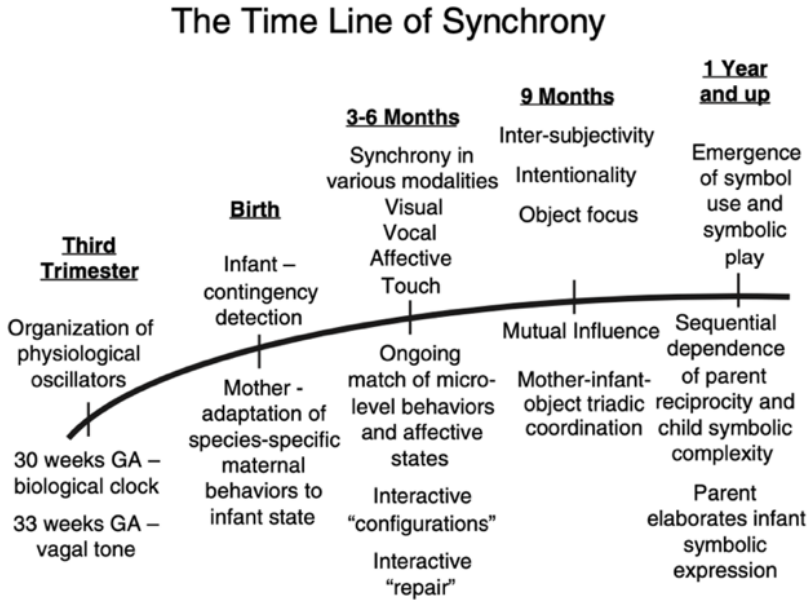

Fig. 1.1 – Interpersonal Synchrony Development (Feldman, 2007)

The picture above *(Fig. 1.1)* shows a scheme of the developmental trajectory of interpersonal synchrony proposed by Feldman (2007). The timeline starts from the last trimester of gestation, since it has been found that the biological rhythm provides a neuro-biological substrate for coordinated interaction. In a study by Feldman and colleagues (2007), the Oxytocin level was monitored throughout the pregnancy and during the first month post-partum and the level of mother-child bonding was observed. The study reported an association between Oxytocin and human bonding (affective touch, positive affect, attachment, gaze exchange), and are associated with a specific maternal behaviour, such as checking behaviours (Feldman et al., 2007). Therefore, the parent's presence serves as an external regulator from the very first moment of life, helping their baby to overcome the distress and to learn to respond to social cues. At birth, indeed, the mother-child interaction marks the infants' early experience of social bonding and synchronization: infants appear to detect behavioural contingency and mothers are able to adapt and to respond to babies' cues and needs (Tarabulsy et al., 1996; Feldman, 2007)). During the first few months of life babies in interactions with others build patterns of multimodal synchrony, since they receive different types of stimulation: vocalization, facial expressions, affective display, affective touch, body proximity and movements (Feldman, 2007). Parents, and especially mothers, tend to synchronize their behaviours with infants naturally, trying to be as much contingent as possible with infants' alertness (Feldman & Eidelman, 2007). By the 9th month of life babies develop the inter-subjectivity and both parent and child are responsible for the rhythm of the interaction: babies start to be intentional in the research of social entrainment and to actively engage with their caregiver. Around the first year of life infants start to display symbolic play and gestures to communicate with their parents, their action is goal directed and so is the attempt for a social communication (Feldman, 2007).

From an evolutionary perspective Interpersonal Entrainment in early stages of life contributes to a successful development of social abilities. In his article, Feldman (2007) suggests how important is the mothers' post-partum behaviour to sensitize infants to the temporal dimension of social relationships. There might be a sensitive period in which babies are more easily engaged and trained to understand social rhythms and to develop IS, and as a consequence the social skills such as affiliation, prosocial behaviour, emotional regulation, and empathy. In a context of social deprivation and low social and affective stimulation, it might be that infants show difficulties in perceiving and adapting

to the social and communicative rhythms, and thus to align and behave in sync with others. This would be in accordance with the well-established relationship between a poor sensory and social environment, especially in the first few years of life, and the long-term consequences on both cognitive and affective aspects (Johnson & Haan, 2015).

Many different factors can play a part in changing the typical development of interpersonal synchrony, not just the above-mentioned social deprivation. In her work, Feldman (2007) proposed an overview of all the mother and child conditions that can intervene in the developmental trajectories. Prematurity is frequently associated with disrupted coordination: mothers appear to be more intrusive, less coordinated with the child needs and infants are more irritable, and less able to align and respond to the caregiver's engaging cues. Intra-uterine growth retardation (IUGR) is also linked to a lower ability in emotional self-regulation, difficulties in physiological regulation and in affective communication. The parent-IUGR child relation is very much similar to the parent-premature child couple, resulting in decreased synchronization during the interaction. Moreover, having twins or triplets increase the chance for the babies to be born pre-term or to show some neurodevelopmental disorders. A study by Feldman, Eidelmand and colleagues (2004) investigated parent-infants synchronization, comparing singletons child, twins, and triplets. They found that triplets show less synchronization with their parent, probably since their caregivers are more stressed by the overload of taking care of three children. Thus, parents were less able to coordinate with their 3-months-old triplets. Furthermore, after one year, triplets appeared to be less in distress during maternal separation and shows less approach behaviour during the reunion. The authors found that less synchronization correlated with decreased behavioural reactivity during separation and reunion. It might be that being less in-sync with their parents, makes infants less motivated to seek for them in their absence (Feldman & Eidelman, 2004). From the parent's side, one of the most common barriers in the mother-child relation is the maternal depression. This condition affects the infants' development in the behavioural, affective, and perceptive sphere, as mothers suffering from this condition usually approach the children in a hostile and intrusive way (Feldman et al., 2007). Depressed mothers are not very much capable of being responsive to infants' distress or to fulfil their social needs, indeed they show less joint attention, affective touch, and positive facial expression. Therefore, there is a lack in the display of contingent interaction (Feldman et al., 2007) with cascading effect in the infants' social abilities.

Finally, another risk factor that can intervene and disrupt the typical development of interpersonal synchrony is the presence of a diagnosis of Autism Spectrum Disorder (ASD) (Feldman,2007). This topic has been widely addressed in the literature since this neurodevelopmental disorder is characterized by difficulties in the social sphere and IS has been proven to be an important element in budling social relationship. The present work will focus on this matter and the interpersonal synchrony in the Autistic Spectrum Disorder, which will be addressed in depth in the next chapter.

Chapter II

INTERPERSONAL SYNCHRONY AND AUTISM SPECTRUM DISORDER

2.1 Autism Spectrum Disorder

The *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; DSM–V; American Psychiatric Association, 2013) applied a dimensional approach to classify any mental disorder: it identifies one diagnostic category which include a broader range of symptoms, degrees of difficulties and comorbidity. This new classification required all the diagnostic criteria to be reorganized, indeed the Autistic Disorder is now referred to as Autistic Spectrum Disorder (ASD). The theoretical reframing allows this neurodevelopmental disorder to put together different cognitive and behavioural manifestation, highlighting the heterogeneity of this functioning modality. The DSM-V diagnostic criteria present a symptomatic dyad that characterize the ASD: a social communication deficit and a behavioural deficit. Criterion A refers to a "*Persistent deficits in social communication and social interaction across multiple contexts*". It includes deficits in social-emotional reciprocity, in non-verbal communicative behaviours useful to establish a social interaction and deficits in developing, maintaining, and understanding relationships. Criterion B focus on "*Restricted, repetitive patterns of behavior, interests, or activities*": there could be stereotyped or repetitive motor movements, use of objects or speech; an inflexible adherence to routines or ritualized patterns of verbal and non-verbal behaviour; a highly restricted, fixated interests that are abnormal in intensity or focus and a hyper- or hypo-reactivity to sensory inputs (APA, 2013). To be included in the spectrum, the symptoms need to be presents from and early stage of the development, sustained throughout the development and pervasive. Despite this clear distinction of symptoms, the manifestation varies a lot depending on the combination between the communicative and the behavioural deficits, the developmental age, the language abilities, the severity of the symptoms and the comorbidities with others neurodevelopmental disorders or medical conditions. Therefore, the DSM-V suggest three levels of impairment that are determined by the interaction between the social communication skills, the presence of restricted interests and repetitive behaviours: severe, moderate, and mild impairment (APA, 2013).

The word autism derives from the Greek "*autos*", which means "*self*" and the common preference, or symptom, to be alone has also been called "*autistic aloneness*" (Kanner, 1943). Indeed, the main difficulty for the people in the spectrum is in the social area, manifested with this "aloneness" and which can include difficulties in basic mechanisms, such as eye contact, but also more complex social abilities, such as understanding and sharing emotions with others (American Psychiatric Association, 2013). Indeed, ASD infants and children appear to have unusual responses social cues and they are not attracted from their parents' voice or from familiar faces and gaze. Typical developing children show preferences for social stimuli and people over objects and for the biological movement over mechanical movement, while this is not found in ASD children (Vivanti, 2021). Starting from the fist studies published on the matter, the psychiatrist Leo Kenner in 1943 highlighted the characteristic of this way of functioning. Specifically, in his paper he wrote that the children he observed "*have come into the world with innate inability to form the usual biologically provided affective contact with people*" (Kanner, 1943).

Eye contact is one of the first means of communication that, since the early life, makes the newborns in contact with their parents and caretaker. Research have investigated infant's perception and preferences on eyes: typical developing children preferer to look at adult's direct gaze and towards smiling faces (Farroni et al., 2002; 2007). In ASD children, instead, it is observed an atypical gaze pattern, since they appear not to be attracted from the eyes: indeed, and absent or reduced eye contact is one of most common indicator of ASD traits. For example, an eye-tracker study by Boraston and colleagues (2007) found that a group of ASD looked more to the mouth area compared to TD control group, who focused more on the eyes-area. This prevents ASD children and adults to use the eyes as cues and, as a cascading effects, they find difficult to notice face expression, emotional states, judge social situations and to understand irony (Boraston et al., 2007).

An important element in social interaction is the joint attention, which is what allow a couple to give attention or to talk about something else, external from the dyad (Vivanti, 2021). Attention's defects have been found in ASD individuals, more specifically in joint attention. A study by Vivanti and colleagues (2017) investigated the joint attention and social attention, thanks to the eye tracking technique, involving ASD

and TD adults. The joint attention task asked participants to follow another person's eye gaze and to redirect the attention toward an object (congruent condition), as the partner did, or toward a second object which was present at the same time (incongruent condition). The regions of interests were analyzed, to see if there was a higher fixation on the partner's face, on the congruent or on the incongruent object. The outcome of the eye tracker study showed that ASD participants had trouble in following someone else eye-gaze and in spontaneously engaging their visual attention with the target of other's attention: the ASD group showed diminished attention toward the partner's face as well as in the pre-shift period (Vivanti et al., 2017). This reflects the well-known diminished engagement with social stimuli that is central in the ASD population. Indeed, the study also tracked the preference for social and non-social stimuli: the analysis of visual attention showed that the TD group preferred the social stimuli, while the ASD group didn't show any preference, supporting the idea of an abnormal social attention in ASD (Vivanti et al., 2017).

2.1.2 Theories about social difficulties in ASD

Many theories tried to explain the ASD atypical social interactional pattern, such as the Theory of Mind deficit (Baron-Cohen et al., 1985), the Central Coherence Theory (Frith & Happé, 1994), the deficit in the Executive Functions (Militerni, 2015), the Social Motivational Theory (Chevallier et al., 2012) and the Social Brain approach (Johnson & Haan, 2015).

Theory of Mind (ToM) refers to the one's own ability to infare other's state of mind, beliefs, desire, emotions, and intention, and it is also referred to as "mind-reading": this allows to comprehend others, taking the other's perspective, and facilitate social interactions. ToM can also be an umbrella-term to refer to the Social Cognition, which is the ability to understand social contexts, reflect and interpret the self and others' behaviour and mental states. These skills can be found around the age of 4 in typical developing children (Militerni, 2015). A deficit in this ability is associated to a deficit in the social information processing and in understanding other's mental state, as it happens in the ASD: the blindness towards others state of mind led Baron-Cohen to address ASD people as "mind-blinded" (Baron-Cohen et al., 1985). To prove this blindness, Baron-Cohen and colleagues, in 1985, investigated the Theory of Mind using a false-belief test (Sally-Anne Paradigm, where there is an unforeseen displacement of an object) and

compared the performance of an ASD group with a Down Syndrome Group. They found that the second group could perform well in the test and showed a developed ToM, while the ASD group failed the test, supporting the idea of a deficit at this level. The Theory of Mind deficit could be a result of an atypical development of the joint attention and of the pointing abilities, since they are two basic precursors of the mind reading process (Rollo, 2020). Therefore, ASD individuals cannot acquire this ability: in this perspective also typical developing children prior the 4 years of age should behave as an ASD child, which is not true. Moreover, lots of ASD can develop a basic Theory of Mind, but their diagnosis and their difficulties in social interaction remain, thus this theory is not sufficient to account for the social impairment in ASD (Militerni, 2015).

In addition to the theory of mind deficit, a classical theory provided a possible interpretation of the ASD functioning: the central coherence theory by Uta Frith (Frith & Happé, 1994). She proposed the idea that typical developed people analyze the environmental stimuli in a global way, to understand the higher-level meaning of the context (central coherence), and the analysis of the details comes later. On the contrary, the ASD perception seems to be focused on the details and on the single elements, rather than on the general context, causing an imbalance in the integration of information at different levels and a lack of central coherence (Frith & Happé, 1994). This theory can explain well the hyper-reactivity to sensory inputs, highlighted in the DSM-V, since perceiving a fragmentized word and not being able to operate a multimodal integration could cause abnormal behavioural responses (Frith & Happé, 1994; APA, 2013). The social deficits that characterize the Autistic Spectrum Disorder can also be read from the Central Coherence Deficit perspective: in social situations a fast analysis of detail can be useful to build up a global viewpoint. Thus, the polarization of the attention towards the details don't allow to look at the bigger picture and could be the cause of the problems in the understanding of the ongoing social situation and of the dynamics of social interactions (Militerni, 2015).

Another model to explain the social difficulties is the Executive Function (EF) Model. EF are all the cognitive function driven by the frontal lobes that concur in the planification, organization and control of actions (working memory, attention, online monitoring, flexibility) (Militerni, 2015). People with ASD show a decreased top-down control and lower control of the cognitive function by the prefrontal cortex, which could

explain some behavioural manifestation, such as the impulsivity and the inability to delay the behavioural responses, the lack or the decrease of cognitive and behavioural flexibility and the need for sameness and for repetitive stimuli. Furthermore, EF are fundamental in the problem-solving process, which is needed in social environment where individuals need to understand complex situations and to find solution repeatedly (Militerni, 2015). All those aspects taken together could explain well the difficulties the ASD people manifest with a social interaction and the lack of self-organization in social contexts (Rollo, 2020).

A more recent perspective focuses on the social motivation, which can be described as a "*set of psychological dispositions and biological mechanisms biasing the individual to preferentially orient to the social world (social orienting), to seek and take pleasure in social interactions (social reward), and to work to foster and maintain social bonds (social maintaining)*" (Chevallier et al., 2012). The Social Motivational Theory is a summary of all the findings on typical development of social interests. Indeed, TD are oriented towards social stimuli since early life and perceive the social world as rewarding: this is sufficient motivation to seek for collaborative interaction and for prologued engagement with the social partner. Those motivational-driven (social) behaviours seem to be absent or reduced in the ASD population, since their attention is not very much attracted by the social stimuli and thus less social orienting, social reward and social maintaining behaviours are found (Chevallier et al., 2012)

Finally, from a neuroscientific perspective the theme of the so-called social brain offers a contribution to the theories on typical and atypical social functioning. It has been found that specific areas, or circuits, are involved in the processing of social stimuli: the cortical structures involved are the superior temporal sulcus, the fusiform face area, and the orbitofrontal cortex, together with subcortical areas such as the amygdala and the pulvinar (Johnson & Haan, 2015; Elsabbagh & Johnson, 2016). Those areas are activated during face processing, during emotional recognition and processing, biological motion recognition and during social stimuli discrimination. An atypical activation of the social brain circuit is a possible explanation for the social deficits in the ASD population. Indeed, it has been found a decreased activation of the amygdala during face expression perception tasks and Theory of Mind tasks. Moreover, neuroimaging studies found an abnormal activation of the fusiform gyrus, involved in face recognition; in the superior

temporal sulcus, involved in social signal detection; and in the dorsomedial prefrontal cortex, involved in the high cognitive processing and on the top-down control (Tambelli, 2017; Elsabbagh & Johnson, 2016). Kaiser and colleagues (2010) run a fMRI study with a 4 to 17-years-old, investigating ASD, TD individuals and unaffected siblings (US) of children with ASD to address the brain activation in response to biological motion and scrambled motion. The biological motion perception seems to activate the social brain network; therefore, an atypical activation of this pathway is expected in the atypically developed group. Indeed, the results showed a dysfunction in the right superior temporal sulcus, in the bilateral fusiform gyrus, in the left ventrolateral and ventromedial prefrontal cortex found in the ASD group, which was slightly present in the US group and absent in the TD group (Kaiser et al., 2010).

2.2 Interpersonal Synchrony in Autism Spectrum Disorders

Difficulties in interacting with the others may also be linked to a difficulty in engaging in interpersonal synchrony, both in daily life and in experimental settings. As mentioned in the previous chapter, many factors can interfere with the development of interpersonal synchrony and being in the Autism Spectrum Disorder can increase the probability to fail in synchronizing with others (Feldman et al., 2007). Indeed, the atypicality in social interaction has been found to relate with atypical physiological, neural, and behavioural synchrony and individual in the autistic spectrum disorder are less entrained compared to individuals with typical development (TD) (McNaughton & Redcay, 2020).

Just a few studies have been carried out to understand how physiological synchrony works, and the majority are focused on TD child-parent dyad. A study on the HPA axis (hypothalamic-pituitary-adrenal axis) by Saxbe and colleagues (2017) tried to find a link between the cortisol level in an ASD and in a TD group and their parents during a series of interaction tasks. The cortisol level appeared not to be synchronized in the mother-ASD child dyads, while the linkage was stronger with the TD children, where mother's level of cortisol could predict the child's one (Saxbe et al., 2017).

As for the neural synchrony, a study by Kruppa and colleagues (2020) used the hyper scanning technique to test child-parent dyads, involving both ASD and TD children. They used the functional near infrared spectroscopy to assess the participants'

synchronization during cooperative and competitive tasks. The results highlighted an increase of brain-to-brain synchronization during the cooperative task in the TD child-parent group; on the contrary, the ASD child-parent group didn't show significant increased neural synchrony (Kruppa et al., 2020).

The behavioural synchrony literature on ASD investigated both the verbal and the non-verbal synchronization. Conversational synchrony has been investigated with structured tasks, in which the experimenter uses specific labels or sentences and then assesses if and how the child uses it, otherwise more ecological tasks have been used. Allen and colleagues (2010) investigated the conversational synchrony by using a card-description game: partners had a few cards and they had to describe them to see if they matched. Experimenters described their cards first, by using either an active ("*The lion scared the nurse*") or a passive ("*The queen is being kissed by the sheep*") sentence and children had to respond by describing their cards too. Children showed a strong tendency to use the same syntactic structure that the experimenter used: this was found both in the ASD and in the TD group. The results suggest that in a highly structured and scaffolded environment, ASD can be in-sync with a conversational partner (Allen et al., 2010). Different results were found in more ecological context: Nadig and collegues (2015) proposed a study in which the participant had to describe a few figures to a partner during repeated round of interaction. The partner had to interrupt the activity and leave the room and the game started again when either the old or a new partner came back. The results showed that the TD group was able to adapt rapidly to the new partner and to a new way of describing the picture that helped the understanding. On the contrary, the ASD group had more difficulties in adapting to the new partner's lexical needs and in aligning in the use of language, taking more time to show the entrainment required (Nadig et al., 2015). It's important to notice that those studies involved high functioning ASD with no language impairment, so it wouldn't be accurate to generalize those abilities to adapt and synchronize, especially in highly structured environment, to the whole spectrum.

Finally, the motor component of behavioural synchrony has been found to be decreased or absent in the ASD population by many experimental studies. This topic has a central importance in this work, therefore a series of studies on the motor interpersonal entrainment will be presented later on in the chapter.

The overall conclusion is that ASD children appear to have a general impairment in all the Interpersonal Synchrony levels (behavioural – conversational and motor IS, neural IS and physiological IS), both in spontaneous an induced IS condition.

Not only being diagnosed in the spectrum can interfere with the development of the interpersonal synchronization, but also being a sibling of an ASD child, since it appears to be a risk factor. Research has found that having a family history of autism spectrum disorder increases the probability for infants to display ASD characteristics behaviour and to be diagnosed. Studies on High Risk (HR) and Low Risk children (LR – known to have no ASD relatives) confirmed the increased possibility to being assessed as ASD or to show sub-threshold symptoms and lower level of developmental functioning (Messinger et al., 2013; Vivanti, 2021). Consequently, also the synchronization results to be influenced by the high-risk condition. A study by Yirmiya and colleagues (2006) compared siblings of children with ASD (HR group) with siblings of children with typical development (LR group). The infants were test at 4 and 14 months: synchronization was observed through a session of mother-child free play, during the still face paradigm and coding the name-calling responsiveness. At 14 months was administered also the Early Social Communication Scale (ESCS), a structured assessment to measure non-verbal communication skills, such as joint attention and requesting behaviours. At 14 months the HR group initiated less interaction and non-verbal requesting gestures compare to the LR group and 4 months old that showed more neural affect during the Still Face Paradigm, initiated fewer joint attention behaviour at 14 months, therefore the research for social interaction is lower compared to the LR group. Finally, regarding the synchronization, the HR group resulted to be less in-sync with their mothers during the interaction at 4 months, during the infant-led condition (Yirmiya et al., 2006).

Many claims have been made about the origins of this lack of social abilities and reduced synchronization levels found in people with Autistic Spectrum Disorder. A very old psychoanalytic view proposed that the cause of difficulties in social relationship could be found in the lack of contingent responses given by the mother to the child (Greenberg et al., 1987). This point of view was highly supported by the theoretical perspective of Margaret Mahler, one of the pioneers of the psychoanalytic school. She described the infants' development and has called the first period of life as the "normal autistic phase": this term referrers to the apparent lack of interest for social interaction, since the priority

are to satisfy the physiological needs (sleeping, eating and homeostasis) and to protect from the strong sensory stimulation coming from the environment. In this phase there is correspondence between the baby's need to be taken care of and the mother willingness and capability to take care of him/her. When this correspondence it's disrupted and the mother cannot provide contingent responses to the child's need, child's withdrawal behaviours and a lack of interest for others would emerge, therefore what Mahler called "autistic psychosis" (Greenberg et al., 1987). This condition was the consequence of a vulnerability of the infant, who couldn't perceive as rewarding the interaction with the mother, and therefore of the lack of contingent interaction between mother and child (Tambelli, 2017). Even though this blaming approach to the mother's role is outdated, and the ASD is proved to have multi-causal etiology, it's important to notice that the influence of the temporal and behavioural contingency in the child-caregiver interaction, and in the development of interpersonal synchronization, was highlighted already in the mid-1900s. As said in relation to the typical development, it is also true that many papers on atypical development and ASD introduce the importance of the temporal contingency in the establishment of the Interpersonal Synchrony, without going in depth on the topic, therefore a broadening of this literature field is needed.

2.2.1 Temporal contingency of social stimuli – responsiveness

Temporal contingency refers to the closeness between an action and the environmental answer. When talking about children it can be seen as the temporal link between what a child does, and the response given by the caregiver (usually the parents). The caregiver needs to be responsive to the infant's need, by noticing the behaviour and understanding which are the requests associated to it. The infant, on the other side, understands the relation between request and answer, perceives the interaction as rewarding and develop increased interests in the environment and in the others. Therefore, when there is lack of contingency in the interaction, a lower interest in the social partner is expected, at least in the typical development (Murray, 2015). This might be an explanation for the decreased social interest, and as a cascading effect, the difficulties in the social interactions, that are peculiar of the Autistic Spectrum Disorder.

As said before, the literature on the theme is very much limited and much more research need to be done to dig dipper in the theme. However, a limited number of studies provide some initial knowledge on the topic. For example, a study by Klin and colleagues

(2009) investigated the contingency detection in a non-social context and in a social one, by using a series of point-light animations. For the social context, the experimenter presented a configuration of lights that simulated the biological motion, together with a human vocalization that simulated the "peek-a-boo" or the "pat-a-cake" games. For the non-social stimuli, the animation was presented in an upside-down configuration, in which the biological motion was disrupted, while the contingent soundtrack was kept. A typical developing group and an ASD group have been tested. Results showed that the TD group prefer to look at biological movement over non-social stimuli in which there was temporal contingency between audio and visual presentation. On the contrary, the ASD group appeared to prefer any presentation in which there was an audio-visual synchrony in the stimuli, which suggest a preference for contingency rather than for social over non-social stimuli (Klin et al., 2009). The authors suggest that those results about biological motion are consistent with the diminished attention for eyes and less expertise for social interaction showed in the daily life by the ASD group. Moreover, it's important to highlight their sensitivity for the synchronization, specifically for the contingency between motion and sounds.

In another study, Northrup and colleagues in 2017 investigated the responses to changing contingency, by using a noisy rattle and a silenced one, with infants with high (HR group) and low risk (LR group) for Autistic Spectrum Disorder. The hypothesis of the study states that young infants with ASD or with High Risk for ASD would show deficits in detecting and responding to contingencies in their environment (rattle's sounds and movement) and would have difficulties in using prior experiences to make inferences about future interaction (silenced rattle). Experimenter presented first the noisy rattle and then the silenced one: at 10 months the LR group showed signs that they expected the second rattle to make sounds, showing an anticipation due to a previous experience, while the HR group did not. Therefore, the results confirmed that the HR group had more difficulties in anticipating future events, probably due to a deficit in learning predictive relationship or structural regularities in the environment and in generalizing that information (Northrup et al., 2017). This might explain why the ASD population prefer predictive and repetitive stimuli compared to new stimuli to whom they need to adjust, and why in a complex and changing social context they have difficult in adapting. Furthermore, this study found out also that both HR and LR groups respond to the contingency, showing that there are no difficulties in detecting the temporal closeness

between stimuli. However, the authors highlight that social contingency are more complex compared to the sound-movement contingency used in the experiment, which is consistent with the previous fundings by Klin and colleagues (2009). Hence learning from past contingency, generalizing that knowledge, and anticipating the future events might be harder and have a greater negative impact on social interaction. (Northrup et al., 2017).

Taking all this knowledge together it might be hypothesized that a simple and contingent non-social and social stimuli should be detected by the ASD population, as well as in the High-Risk infants. Moreover, it might be expected that contingent stimuli would elicit an engaging response and active research for the contingency and for the synchronicity in the stimulation, while less contingent stimuli would decrease the social engagement and increase the avoidance of the stimuli. On the contrary, more complex social stimuli could be expected to be less engaging for the ASD population, even though the contingency of the stimulation.

2.2.2 Social engagement – communicativeness

Temporal contingency and the responsiveness are not the only element that might influence interpersonal synchronization; indeed, the communicativeness of the stimuli and the social engagement seem to play an important role and enhance the social entrainment, at least in the typical developing population. Farroni and colleagues (2002; 2007), together with many other authors, demonstrated that TD children are attracted to the faces that engage with them through a direct gaze. On the contrary, the averted gaze (if not preceded by direct gaze), is not attractive since it doesn't help the social engagement and the communication between the two individuals. Those results are congruent with the Social Motivational theory (Chevallier et al., 2012), which states that the social stimuli are more attractive compared to non-social elements, since they carry a motivational and rewarding value, and enhance the behaviours to maintain the social interaction. Thus, a direct gaze, which capture the other's attention, carries a high rewarding value, it's liked and wanted by the individuals, who try to engage even more with the stimulus. In the ASD population opposite results have been found, indeed here the attraction for the direct gaze is reduced or absent and a general decreased interest for faces has been found (Boraston et al., 2007). Moreover, the motivational driven behaviours, such as social orienting, seeking, and liking and social maintaining seems to

be absent or decreased in ASD, highlighting a lower interest for the social world and for social engagement (Chevallier et al., 2012).

Another element that might interfere with the social engagement is the sensory processing: one of the diagnostic criteria refers to the hyper- or hyposensitivity for sensory stimulation, which include the visual, tactile, and auditory systems (APA, 2013). This might include a range of responses from a high sesation seeking to the complete avoidance of stimulation or to aggressive behavioural responses. In line with the diagnostic criterion, Dunn (2007) proposed model of the sensory processing, which is useful to describe the atypicality in the sensory thresholds within the atypical population. He proposed that two dimensions, the neurological threshold (low VS high) and the self-regulation (active VS passive),which might be combined to form four different sensory profile, thus four different responses to sensory stimulation. The four patterns are: sensation seeking (high thresholds, active self-regulation strategy) , sensation avoiding (low thresholds, active self-regulation strategy), sensory activation (low thresholds, passive self-regulation strategy) and low registration (high thresholds, passive self-regulation strategy). Moreover, each individual can display different sensory modalities which are stimulus-specific, so for example an ASD child could seek for repeated and loud sounds and at the same time refusing the physical contact with another person since it's perceived as overwhelming (Dunn, 2007). This could be a valid explanation for the social difficulties, both in regulating the behaviour within a social context and in responding to social stimulation. Another possible explanation takes in consideration a possible impairment in the multimodal sensory integration, leading to difficulties in perceiving and processing sensory stimuli, which might be interpreted as too strong a complex to be integrated, or too delicate and not captivating. The difficulties impact on the processing of social information and in the social interaction: it might be at the basis of language and communication impairment, but also in the development of social skills such as the imitation and the coordination with other, the theory of mind and the empathy (Marco et al., 2011). Moreover, during daily life social interaction it's fundamental to integrate different social stimuli, such as facial expressions, voices, postures, and gestures, to fully understand and relate to the social environment, and to flexibly adapt to the changes in those stimuli. Instead, ASD people tend to be fixated on simple stimuli, to avoid changes and to seek for sameness in the environment, which are not the characteristic of social stimuli, therefore engaging with others might be either too difficult

or not as much interesting, attractive, and rewarding as it is for TD people (MARCO et al., 2011, APA, 2013, Chevallier et al., 2012).

2.3 Motor Interpersonal Synchrony

As introduced earlier, the motor interpersonal synchronization has been widely investigated in the research field: the studies have involved both the typical and the atypical population, of different ages and in a variety of context. The higher number of studies on Motor IS might be due to the fast that it's easier to test and measure compared to the other types of IS, but also because it has a great importance in the social interaction since the very first moment of life. For the purposes of the present work, a series of evidence and research about motor IS will be presented, taking in consideration the typical developing population and the ASD population.

An example of motor IS study is the one proposed by Marsh and colleagues in 2013: they used the rocking chair paradigm to test parent-child dyads, where children could be either in the TD or in the ASD group. In this task the parent had to rock throughout to a set tempo while reading a storybook to the child, who was sitting on its own rocking chair. The movement of the child was measured and compared to the parent's one to see if they spontaneously rocked in-sync with their partner. The outcome was that the TD group exhibited more in-phase rocking behaviour with their parents, and thus they were more synchronized, compared to the ASD children group (Marsh et al., 2013). Another study by Kaur and colleagues (2018) investigated the motor synchrony in a group of TD and low and high functioning ASD children, aged 5 to 12. They study proposed a motor coordination experimental paradigm, in which six actions (simple and complex clapping, simple and complex marching and simple and complex drumming) were asked to be performed in-synch with and adult partner. Research measured the percentage of time the child perfectly synchronized his/her actions with the tester (in synchrony) or not (out of synchrony). The outcome showed that both low and high functioning ASD group spent significantly less time in synchrony than the TD group in all the action prosed (Kaur et al., 2018).

Motor IS had been investigated also in the adult population, like in the study by Georgescu and colleagues (2020): 29 ASD adults and 29 TD adults have been paired in to form 10 ASD dyads, 10 Typical dyads and 9 ASD-TD dyads. Participants have been

asked to participate to a series of task in which they had to conversate with their partner and the motor synchronization of the head and of the whole body have been analyzed. Whole body motor IS differences has been found between the TD couples and the ASD and ASD-TD couples has been found, therefore dyads with at least one ASD participant resulted less entrained compared to the TD couple. Moreover, the experimenter asked to rate the interaction pleasantness, and they found that the TD perceived the conversation as more pleasant, which is probably linked to the higher synchronization within the relationship (Georgescu et al., 2020). This study is interesting because it offers an ecological measure of the motor IS, since it presents a conversational setting similar to one in the daily life, but also because it provides evidence for a link between being in-sync with a partner and the pleasure which comes with the interaction.

It is thought that motor difficulties, including low levels of motor interpersonal synchrony, are very much linked to social communication difficulties. The evidence presented above might support this idea, since the difficulties in social communication are a peculiar trait of the ASD profile and are usually accompanied by motor difficulties and by a lower ability to get in-sync with a partner. Furthermore, a decreased responsiveness to the social synchronization appears to be present from the first moment of life, therefore studying motor symptoms and difficulties could help for an early identification of the ASD traits, and thus an early intervention (Dowell et al., 2009; Kaur et al., 2018).

2.4 Research line of the Thesis

The present work aims to add knowledge to the existing literature on the topic of Interpersonal Synchrony, by investigating the role of temporal contingency and social engagement, as well as revising the literature on Motor Interpersonal Synchrony.

The matter has been analyzed through a meta-analysis which investigates the Motor Interpersonal Synchrony, by including dyadic studies which confronted ASD and TD group, to provide the state of the art on the topic and quantify the effect size of the phenomena. Indeed, the main aim of the meta-analysis was to investigate whether the ASD population, compared to the neurotypical one, showed reduced interpersonal motor synchrony during social exchanges.

As a further step, a second experiment has been run by administering an experimental paradigm to children and adolescents aged 3 to 18, divided in a Typically Developing and an Autism Spectrum Disorder group. This task allowed to test if some elements, such as the contingency and the communicativeness of the stimuli, contributed to the atypicality found in the interpersonal synchronization in the ASD population. The task required participants to rate faces before and after interacting with them. During interaction, they make choices based on their spontaneous preference; the 4 stimuli (female faces) respond either in a contingent or in a non-contingent way and that are either engaging or non-engaging, to see it those variables influenced the choices.

Chapter III

META-ANALYSIS ON MOTOR INTERPERSONAL SYNCHRONY

3.1 Methods and study selection

The study presented in this chapter is a meta-analysis run to investigate the topic of motor interpersonal synchrony in ASD, and to answer to the following research question: "*Do ASD (compared to TD) individuals manifest reduced interpersonal motor synchrony during social exchanges?*". To do so the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA, 2020) guidelines were followed (Page et al., 2021). The searches have been conducted on June 16th 2021, therefore all the studies published later are not included. The databases taken in consideration were EBSCO host APA PsycArticles, APA PsycInfo, Scopus, Pubmed and the search string used was *(TITLE-ABS-KEY(sync* OR coordination OR entrainment) AND interpersonal AND (motor OR motion) AND (autis* OR asd OR asc)*. Inclusion and exclusion criteria were decided to filter the papers.

The inclusion criteria were:

- Language: English
- Source type: Scientific Journals
- Methods: Cinematic measures, human partner, in-person setting
- Sample: Presence of a TD control group and of an ASD group
- Topic: Interpersonal Motor Synchrony
- Design: Experimental

The exclusion criteria were:

- Language: Non-English
- Topic: Not related to interpersonal synchrony, NON-ASD, NON-motor, NON-synch, NON-interpersonal
- Publication type: review/meta-analysis/theoretical,
- Methods: Indirect measure of Interpersonal Synchrony (i.e., questionnaires); observational measures; virtual partner/video, imitation measures
- Sample: Absence of control group, Non-ASD, ASD traits/siblings

The research led to the identification of 427 studies, but by applying all the exclusion criteria 59 studies were selected. Other studies have been excluded since they were meta-analysis, did not include an ASD group or a control group or were out of topic: this led to the analysis of 14 studies. However, 3 groups did not share the missing data, so the study have been excluded from the final data analysis and only 11 paper have been included in the Meta-analysis. The PRISMA (2020) flow diagram below represents the study selection process (*Fig. 3.1*).

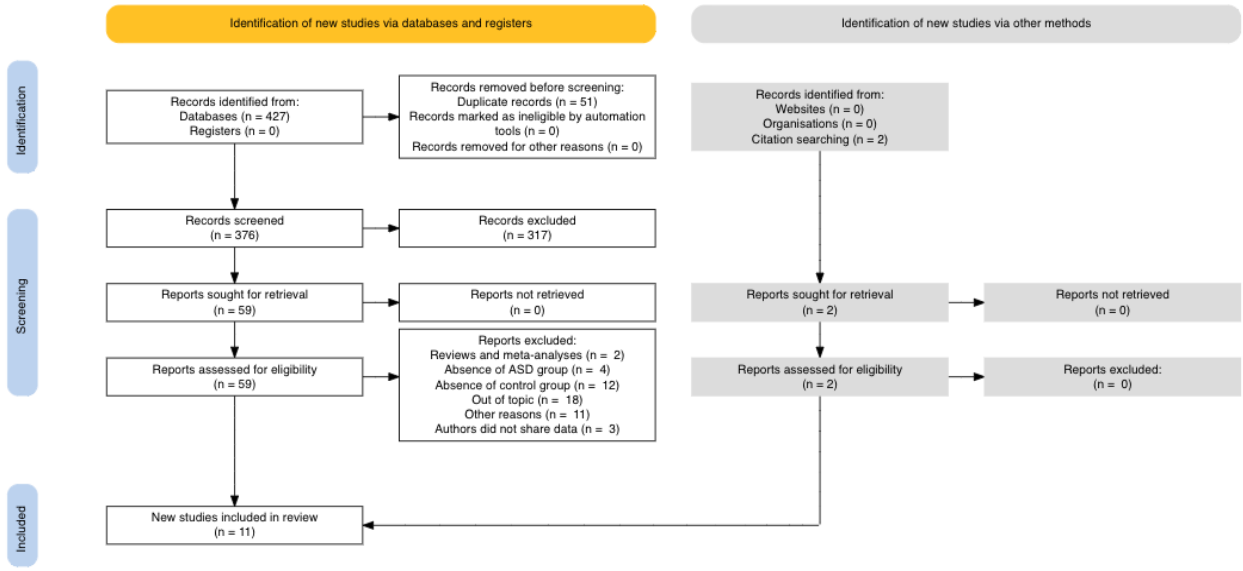

Fig. 3.1 – Flow diagram for study selection

3.2 Procedure

After being selected, the studies have been read and checked by two independent experimenters. A pre-prepared form was filled out with the following information:

- Authors, publication year, DOI and country
- Task proposed
- Measures used
- Outcome data for both ASD and control group performances (mean and standard deviation
- Conditions in which motor IS have been measured
- Type of Motor IS (spontaneous or induced)

- Participants demographics separated for ASD and control group (number of participants; male-female ratio; age range, mean and standard deviation)

All those information are summed up in the table in the results section (see *Fig. 3.2*)

3.3 Data analysis

The statistical analysis was carried out on R (R: The R Project for Statistical Computing (https://www.r-project.org). For each study, the mean, and the standard deviation of the outcomes of the measures of interest were collected. Since the studies used different tasks and measures to evaluate the Motor Interpersonal Synchrony, the outcomes needed to be adjusted to be comparable, therefore the effects size were calculated. We used the function *"escalc"*, from the R package *"metafor"*, to calculate the effects size. We calculated the effect size of every single measure by finding the Cohen's D, which is the difference between each group's mean (ASD outcome mean and the TD outcome mean), divided for the pooled standard deviations for the two groups. However, this value doesn't take in consideration the number of subjects while computing the effects size. Therefore, the results were corrected for the sample size, meaning that we calculated the Hedge's g (Hedges, 1981). Finally, the function *"agg"*, from the *"Mad"* package in R, was used: this aggregated the multiple effects size and created a single combined effect size for each study. To do this computation we needed to define the correlation among the measures within the same study, which is unknown. We hypothesized a correlation of 0.50 (r=.5). Those final measures of effect size allow us to compare the effect size of each study, and thus to analyze the differences between the distributions of ASD and TD groups when assessing Motor Interpersonal Synchrony.

For the meta-analysis process, we decided to use the random-effects model. This model assumes that the results come from a sample of a population of studies and therefore the meta-analysis outcomes could be generalized to all the population. This modelling approach also considers variability between effects sizes, which is plausible from a theoretical perspective, even though the study sample is quite small.

The heterogeneity of the studies was further evaluated: it refers to the variation in the outcomes between studies and to this purpose, the Q-statistics were carried out. Also, the I^2 value was calculated, and it describes the percentage of variation across studies; if

high, it suggests that differences among effect sizes can be related to an actual difference between the characteristics of the studies.

Finally, the publication bias might influence the papers that can be found: most of the studies that are published present significant results on the evaluated matter. When those results are not significant, they might not be published. To check the presence of this bias in our study selection and in the literature, we evaluated it by using the funnel plot. It allows to see if the published studies used in the meta-analysis are distributed symmetrically or asymmetrically in the graph: a symmetric distribution indicate the absence of the publication bias. On the contrary, if there is a bias it shows where there is a lack of publications. It was used the trim and fill method.

3.4 Results

3.4.1 Descriptive analysis

The paper selection included 11 studies, published between the 2013 and the 2020 in the USA, Israel, Germany, and Italy. The studies involved participants of all ages, and studies the dyadic interaction between parents and children and between experimenter and participants. Motor Interpersonal Synchrony tasks were also classified as induced, when participants were instructed to behave in-sync, and as spontaneous, when no instructions were given. All those information are included in the table below (*Fig. 3.2*), together with the sample details for ASD and TD groups (numerosity, male-female ratio, age range, mean and standard deviation), the effects size and the variance of the effects.

			Control Group					ASD Group							
					Age					Age					
ID	Authors	Country	N	M/F ratio	range	mean	sd	N	M/F ratio	range	mean	sd	Synch_type	es	var
1	Brezis et al., 2017	Israel	38	28:7	19 - 45	25.90	6.37	34	31:3	20 - 45	28.60	6.26	induced	0.66	0.03
2	Fitzpatrick et al., 2013	USA	3	1:2	4 - 5.6	4.80	0.75	5	4:1	5 - 7.4	6.21	1.17	induced	0.21	0.34
3	Fitzpatrick et al., 2017	USA	27	21:6	6.33 - 10.8	8.24	1.46	23	20:3	6.08 - 10.75	8.08	1.44	induced	1.00	0.05
4	Fitzpatrick et al., 2016	USA	9	7:2	12 - 16	14.44	1.13	9	8:1	12 - 17	13.67	1.94	induced	0.34	0.13
5	Fulceri et al., 2018	Italy	11	9:2	6.3 - 9.8	7.57	0.71	11	10:1	5.11 - 10.3	7.82	1.32	spontaneous	-0.82	0.11
6	Georgescu et al., 2020	Germany	10	6:4	33 - 51	41.80	8.86	9	5:4	30 - 50	40.72	10.45	spontaneous	0.90	0.12
7	Kawasaki et al., 2017	USA	24	12:12	18.9 - 32.1	25.60	6.60	24	14:10	22 - 36.4	29.20	7.20	spontaneous	0.83	0.09
8	Kruppa et al., 2021	Germany	41	18:23	8 - 18	12.66	2.79	18	18:0	8 - 18	13.54	2.96	spontaneous	-0.62	0.06
9	Lampi et al., 2020	USA	47	34:13	6 - 10	7.85	1.49	50	34:7	6 - 10	8.02	1.44	spontaneous	2.62	0.03
10	Marsh et al., 2013	USA	7	4:3	2.8 - 4.6	3.75	0.12	7	5:2	3.8 - 4.1	3.94	0.74	spontaneous	1.66	0.30
11	Noel et al., 2018	USA	15	11:4	8.9 - 14.5	10.94	2.13	12	8:4	7.9 - 16.5	12.20	3.75	spontaneous	0.00	0.11

Fig. 3.2 Descriptive statistics of the studies included

3.4.2 Random-Effects Model Mata-analysis

The random-effects meta-analysis calculated showed a mean effect size (ES = 0.62, 95% CI [0.02, 1.22], p= 0.042), suggesting that there is a difference between the ASD and the TD group in the Motor IS. However, the confidence interval is quite broad (from 0.02 to 1,22), therefore the effect in the population could be either very small or very big. We cannot exclude the absence of an effect, meaning that there might be no differences between the ASD and the TD groups, because the inferior limit of the confidence interval is very close to 0. The forest plot in the *figure 3.3* shows the effects size of the Motor Interpersonal Synchrony for each study and the global effect size, as well as the weight of each study on the global effect size estimate.

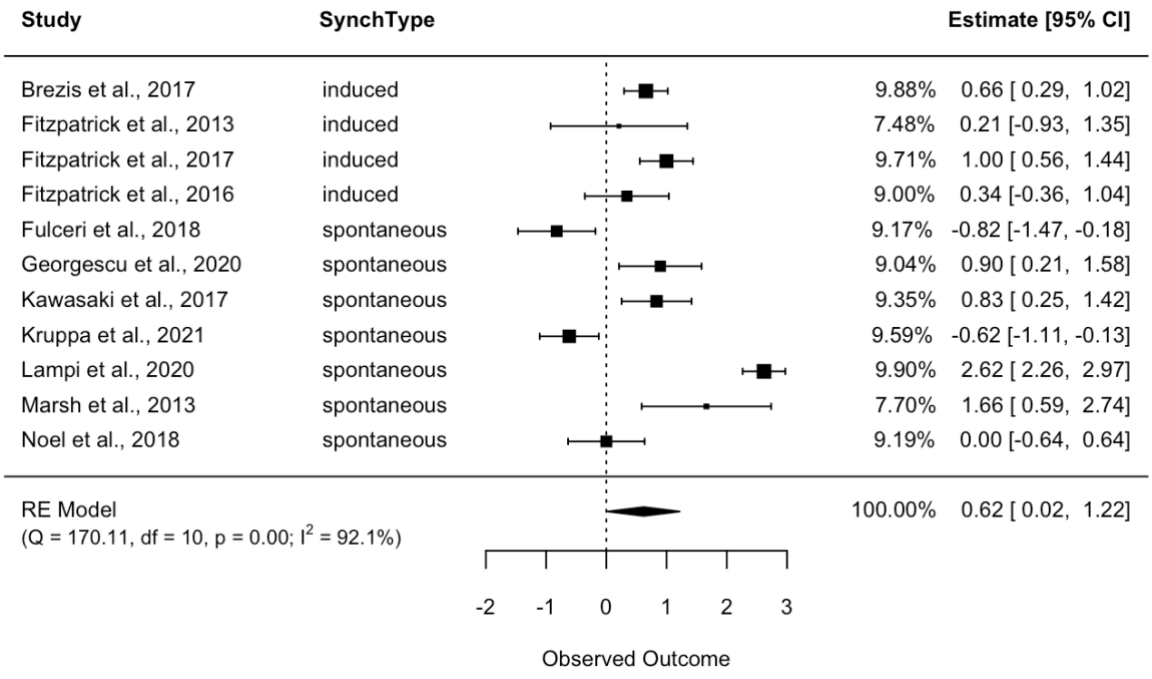

Fig. 3.3– Random-Effects model Forest Plot

The heterogeneity of the studies came out as significant (Q(10) = 170.11, p < .0001): this might be related to the high variability among effects size. Another reason might be linked to the variety of measures used in the considered studies to quantify the Motor Interpersonal Synchrony. This is confirmed by the I^2 index (I2= 92.09%), since the variability percentage of effect size is very high: it suggests that the variability between effects sizes might depend on an actual difference in the characteristic of each study.

The publication bias was evaluated, and the funnel plot (*Fig. 3.4*) shows only one point (the white one) added thanks to the trim-and-fill method, so it can be said that there is no publication bias in the selected studies.

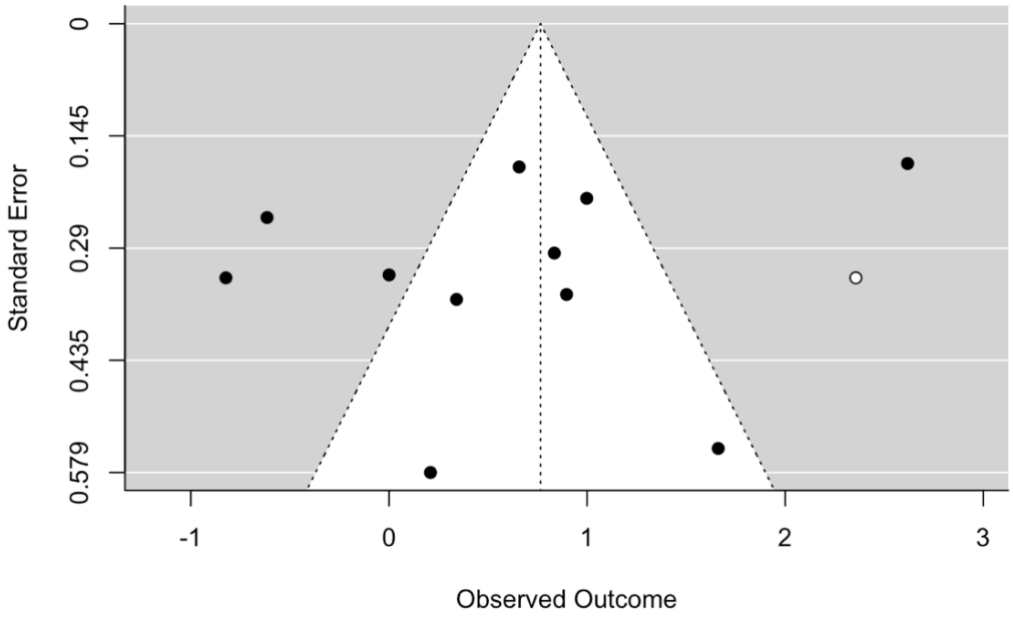

Fig. 3.4 - Funnel plot for publication bias

Chapter IV

THE ROLE OF TEMPORAL CONTINGENCY AND SOCIAL ENGAGEMENT FOR CHILDREN'S SOCIAL PREFERENCES

4.1 Participants

The study involved 23 children and adolescents between the age of 3 and 17, with a diagnosis of Autism Spectrum Disorder (ASD). The control group included 26 typical developing (TD) children and adolescents between the age of 4 and 11 (see *Fig. 4.1*) .

	Sample size	F:M	Age Range	Mean Age	Age SD
ASD	23	1:22	3-17	10,3	3,6
TD	26	15:11	4-11	7,2	1,9

Fig. 4.1 – Participants demographics

The study protocol was approved by the local Ethical Committee of Psychology Research (University of Padua).

4.2 Stimuli and procedure

The participants of the study have been recruited from the University of Padua's *Baby Lab*, in the case of the TD sample, while the ASD participants came from the Therapy Centre *Chelis*, in Venice. Before administrating the test, parents of the ASD and of the TD group have been asked to sign an informed consent, in which they agreed for their children to take part to the study, with the possibility to withdraw at any time.

The study proposed a task on a tablet and was programmed by using *Labvanced*. Firstly, a screen with four faces was presented. Participant were asked to whom they would give a present. When the present was delivered to a face, both the face and the present disappeared; by doing so, participants ranked the faces from their top to their last choice.

Then a screen with four windows appeared: participants had to choose one of the windows, casually, without following any rule, by clicking on the screen. When the windows opened, a face (the same faces as in the first screen) appeared and moved from

a lateral to a frontal position. Two out of four faces always turned as soon as the participant opened the window (contingent faces), while the other two always turned with a time delay (non-contingent faces). Also, engagement was manipulated, with two out of four faces looking towards and smiling at the participant (engaging faces), and other two faces looking down with a neutral expression (non-engaging faces).

Therefore, the faces could be:

- Contingent – engaging
- Contingent – non-engaging
- Non-contingent – engaging
- Non contingent – non-engaging

Participants were presented with 60 trials. If the participant does not make a choice within 2,5 seconds, a hand graphic appears in the centre of the screen and must be touched to move to the next trial, in which case the response counted as omission.

The combination of each of the four face identities, the corresponding condition, and the position of the face within the four windows was randomized among participants.

To further reduce possible preference bias arising from the spatial location of faces, each participant is presented with two blocks of trials in which the spatial location of faces within the four windows is changed.

After the two interaction blocks participants were asked again to whom they would give the present, such that they ranked the faces from the top to the last one as they did at the beginning.

The picture below (*Fig. 4.2*) shows the experimental paradigm with the face preference, the choosing trials and the final face preference expression.

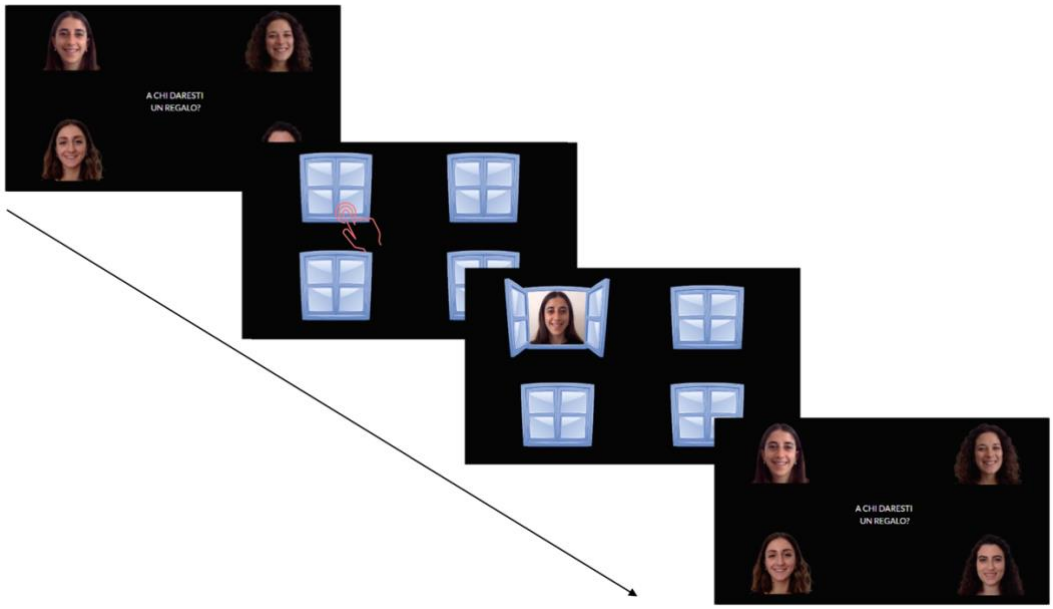

Fig. 4.2 – Experimental paradigm

4.3 Hypotheses

We hypothesize that the TD group would prefer contingency in a communicative (engaging) context, thus we expect a higher number of choices for contingent-engaging faces. On the contrary, due to all the previously presented knowledge on the social difficulties in ASD, we anticipate no preference manifested for engaging VS non-engaging faces. As for the contingency aspects, it might emerge that the ASD found it difficult to detect contingencies, resulting in no preference for contingent vs not contingent faces.

Another hypothesis is linked to the fact that during daily life interactions the contingency aspects might not be always present, due to temporal delays and pauses between actions or due to the a-synchronicity in the interactions. Therefore, the TD group is already used to both contingent and the non-contingent interaction and should not show any preference for the contingent condition. As for the engagement aspects, we expect to find a higher preference for the engaging faces. On the contrary, it should be expected that the ASD group is not as much expert as the TD group in tolerating the non-contingent responses. Thus, they should show a preference for the contingent faces, which respond quickly and without delays. In this group no preference for the engaging VS non-engaging condition is hypothesized.

As for the pre-post judgment, we expect that the interaction phase will modulate the pleasantness and the face choices. Therefore, according to the first hypothesis the TD group should rank as more pleasant the contingent-engaging faces, while the ASD group shouldn't show a common pattern of choices between participants. According to the second hypothesis, instead, we expect that the TD group would rank fist the engaging faces, despite the contingency condition, while the ASD should prefer the faces in the contingent condition, with no influence of the engagement variable.

4.4 Measures

Three dependent variables have been collected and separately analyzed:

- percentage of choices towards each face,
- reaction times
- judgement score indicating the difference between participants' preference for each face before and after the interaction phase (post-pre).

As independent variables, participants' age, stimulus contingency and engagement were included.

4.5 Data analysis

The statistical analysis has been carried out on R (R: The R Project for Statistical Computing (https://www.r-project.org). We adopted a model comparison approach to choose the model that best predicted our data. Linear mixed-effect models, including both fixed effects and random effects have been used. The models investigated both the addictive effects of the independent variables, in which the effect of each variable sums up to the others, and the interaction effects, where two variables are in interaction with one another. The models have been compared by using the AIC (*Akaike information criterion*) and the AICc weight (*Akaike weight*). The first compare models and attribute a higher value to the model that describe the changes in the dependent variables, without losing any information (Wagenmakers & Farrell, 2004). AICc weight is calculated on the AIC difference between the model and the best predictive model, which allow to test the predictive likelihood. This value can be interpreted as the probability that models predict the data and the changes in the dependent variables and that the model with the lowest AIC value is the best predictor (Wagenmakers & Farrell, 2004).

4.6 Results

4.6.1 Choices

The choices made by the participants have been analyzed to understand if they were influenced by stimuli contingency (2 levels: contingent, not contingent) and engagement (2 levels: engaging, not engaging). We used the percentage of choices towards each stimulus (referring to each condition: C-E, NC-E, C-NE, NC-NE) as our dependent variable. This allows to measure, within the total number of trials performed, to which extent the participant choose each stimulus. We decided not to use frequencies because this wouldn't allow to weight the choices made on the valid trial: not all the participants had the same number of trials. Indeed, all the trials in which participants answered before 100ms from stimulus presentation were excluded, since it was too fast, and the participant could not have seen properly the stimuli. The test was also programmed to pause if the answer occurred after the 2500ms, and those trials were considered as "not answered". The total number of valid trials in our sample was 2490.

	C-E	**C-NE**	**NC-E**	**NC-NE**
ASD	0,27 (0,05)	0,25 (0,05)	0,24 (0,05)	0,24 (0,04)
TD	0,25 (0,03)	0,24 (0,02)	0,26 (0,02)	0,24 (0,03)

Fig. 4.3 – Mean and Standard Deviation for Choices

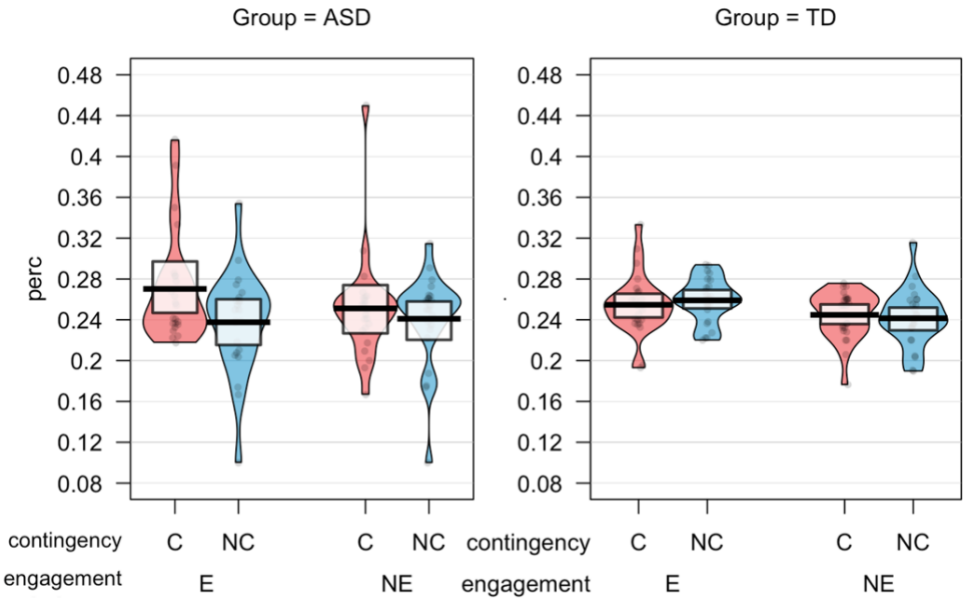

Fig. 4.4 – Percentage of choices made for each condition and in each group

A first step on this analysis consisted in testing if the individual differences account for the changes in the choices made, both for the contingency and the engagement. This was done by comparing a basic model (perc ~ contingency; perc ~ engagement) with the same model including an additional random effect (1 | participant) to consider multiple observations on the same participant. Since we found that the best model was the one that didn't include random effect of participants, this random effect was not taken into account in all the following models.

The studied models investigated the role of the contingency conditions, the engagement conditions, and the role of the group (ASD and TD), considering the additive value of each factor, and the interaction between them (see *Fig. 4.5*).

The best model appeared to be the one that included the interaction between the contingency condition (C-NC) and the group (ASD-TD), and in addition the engagement condition (E-NE) as predictors. This model, indeed, showed the lowest AICc value (AICc = -700.90) and the highest AICc weight value (AICcWt = 0.26), as showed in the outcome presented below (see *Fig. 4.5*).

ID	Model	AICc	AICcWt
Mc1	Perc ~ contingency	-699.24	0.11
Mc2	Perc ~ engagement	-699.49	0.13
Mc3	Perc ~ contingency + engagement	-700.68	0.23
Mc4	Perc ~ contingency*engagement	-698.87	0.09
Mc5	Perc ~ contingency *group + engagement	-700.90	0.26
Mc6	Perc ~ contingency + group*engagement	-696.95	0.04
Mc7	Perc ~ contingency*group + engagement*group	-699.04	0.10
Mc8	Perc ~ contingency*engagement*group	-696.86	0.03

Fig. 4.5 – Model Comparison for choices

Finally, the ANOVA test have been carried out to investigate the effects of the selected model. In particular, the interaction between the continency and group has been observed (p = 0.038). As it can be seen in the graphic below (*Fig. 4.6*), the TD group doesn't show a difference in the percentage of choices made between the faces in the

contingent or in the non-contingent condition. On the contrary, in the ASD group a higher percentage of choices for contingent faces compared to not contingent faces emerged.

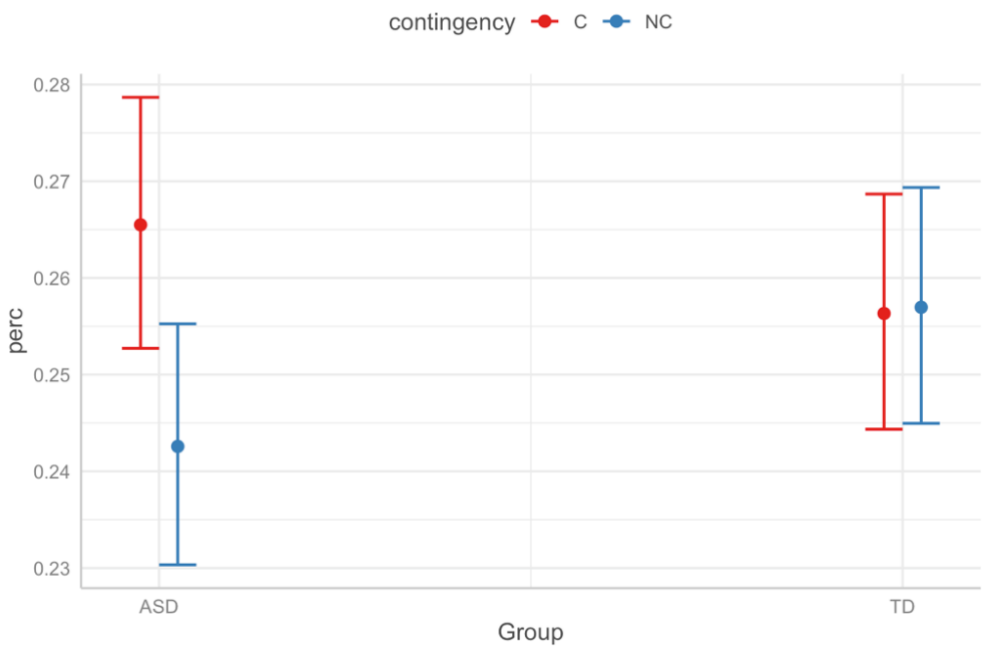

Fig. 4.6. – Interaction between continency and group

In addition, a main effect of engagement has emerged (p = 0.053), with participants choosing engaging faces more frequently than non-engaging faces (see *Fig. 4.7*).

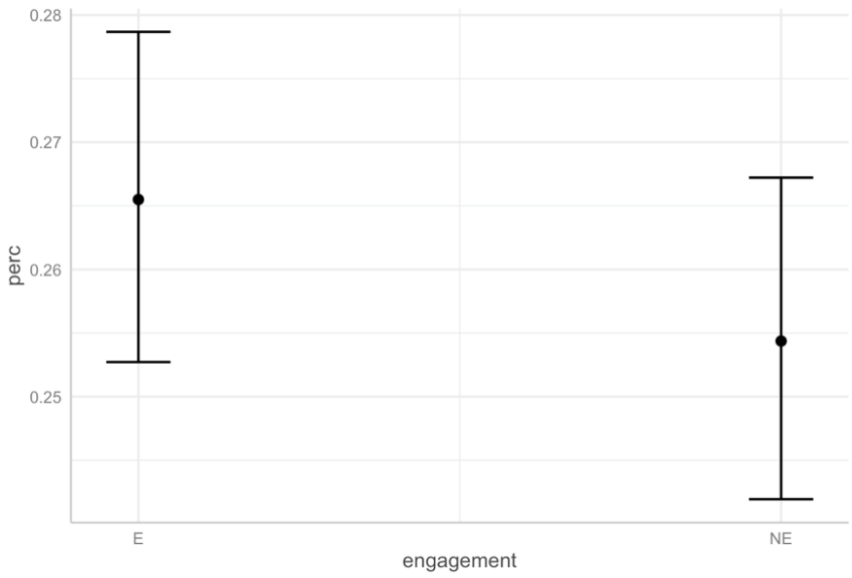

Fig. 4.7 – ANOVA engagement

4.6.2 Reaction Times

The reaction times have been investigated to evaluate the possible effects of the stimuli conditions (C-E, NC-E, C-NE, NC-NE), and therefore the contingency and the engagement variables, which might influence the choices.

	C-E	C-NE	NC-E	NC-NE
ASD	958,52 (520,97)	960,75 (581,15)	979,48 (568,63)	945,79 (480,08)
TD	1087,34 (500,36)	1092,23 (511,45)	1123,85 (511,18)	1097,14 (503,13)

Fig. 4.8 – Mean and Standard Deviation of Reaction Times

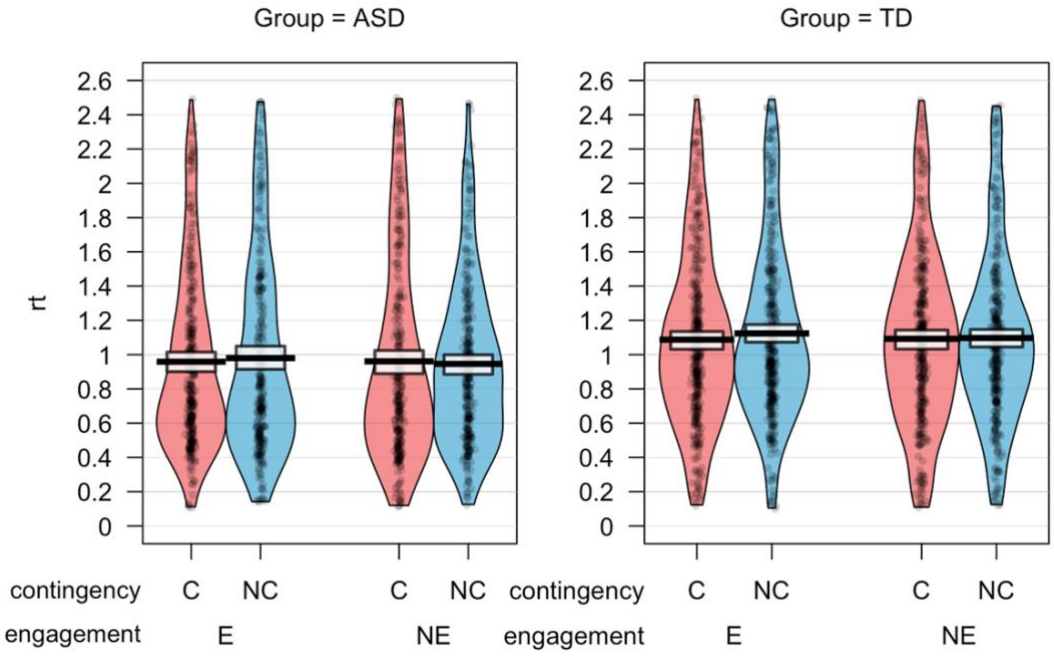

Fig. 4.9 – Reaction time for each condition and in each group

As mentioned earlier, the analysis excluded all the trials in which the answer was given before the 100ms and after the 2500ms. A model comparison has been run, by taking in consideration the following: age, contingency, engagement, random effect of participant to consider multiple observations. Both addictive and interactive effects have been investigated (see *Fig. 4.10*). Even if we did not have any specific research question

on age, this was included in the null model as it is a well-established effect in the literature and thus, we wanted to account for it.

ID	Model	AICc	AICcWt
M0	rt ~ (1|ID) + age	3217.94	0.36
M1	rt ~ contingency + (1|ID) + age	3218.38	0.29
M2	rt ~ engagement + (1|ID) + age	3219.90	0.14
M3	rt ~ contingency + engagement + (1|ID) + age	3220.34	0.11
M4	rt ~ contingency*engagement + (1|ID) + age	3222.11	0.05
M5	rt ~ contingency*engagement + group (1|ID) + age	3224.11	0.02
M6	rt ~ contingency*group + engagement (1|ID) + age	3224.30	0.02
M7	rt ~ contingency + group*engagement + (1|ID) + age	3224.31	0.02
M8	rt ~ contingency*group + engagement*group + (1|ID) + age	3226.28	0.01
M9	rt ~ contingency*engagement*group + (1|ID) + age	3229.81	0.00

Fig. 4.10 – Model comparison for reaction times

The model that best predicts our dependent variable (reaction times) is the one that takes in consideration only the random effect of participant and their age (AICc = 3217.94; AICcWt = 0,36). Furthermore, the ANOVA test showed a main effect of age ($p < 0.001$). The graphic below (*Fig. 4.11*) shows the reaction times decrease as participants' age increases.

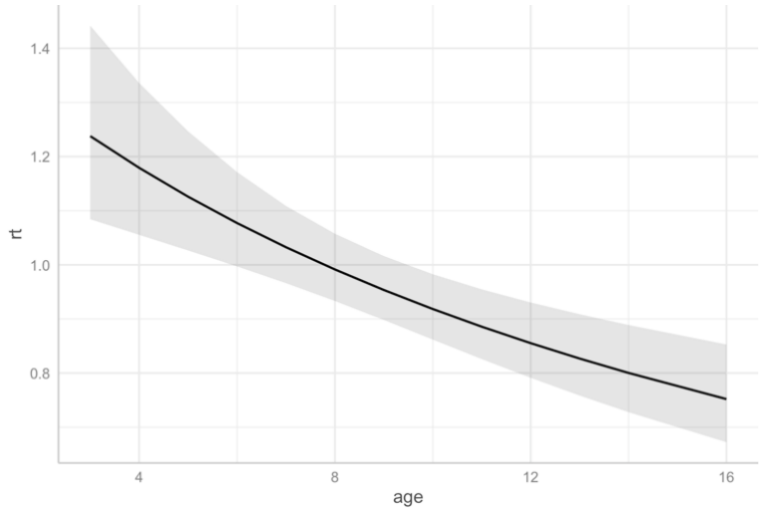

Fig. 4.11 – Reaction time and participants' age

4.6.3 Judgment

The last variable investigated was the judgment: it refers to the change in preferences for each face expressed before and after the interaction trials. The purpose of this analysis was to see if the type of interaction experienced with each face during experimental trials would modify the preference for the faces presented.

	C-E	C-NE	NC-E	NC-NE
ASD	0,22 (1,38)	0.22 (1,35)	-0,35 (1.07)	-0,04 (1,29)
TD	0,50 (1,55)	-0,15 (1,51)	0,30 (1,52)	-0,65 (1,23

Fig. 4.12 – Mean and Standard Deviation for Judgment

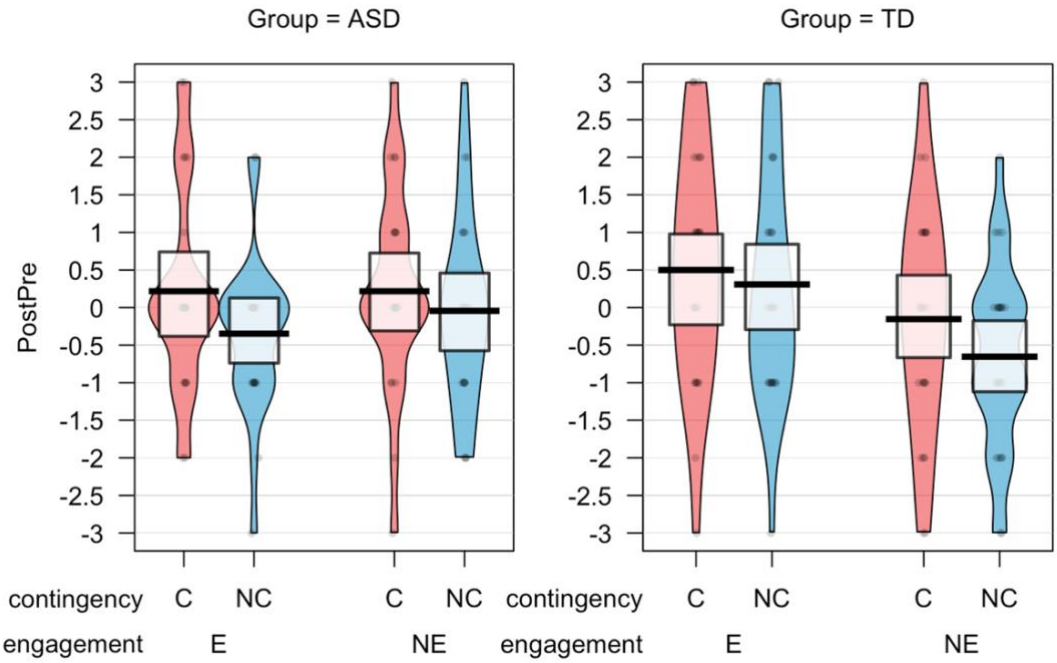

Fig. 4.13 – Judgment distribution across groups and conditions

The model comparison has been run by considering the random effect of participant, contingency, engagement, and the group both as main effects and interactions (*Fig. 4.14*).

The outcome highlighted that the best model to describe the pre-post judgment modification was the one that included only the contingency and the random individual effects (1|ID) (AICc = 696.31; AICcWt = 0.18).

ID	Model	AICc	AICcWt
M0_J	PrePost ~ (1|ID)	696.42	0.17
M1_J	PrePost ~ contingency + (1|ID)	696.31	0.18
M2_J	PrePost ~ engagement + (1|ID)	696.96	0.15
M3_J	PrePost ~ contingency + engagement + (1|ID)	696.57	0.16
M4_J	PrePost ~ contingency*engagement + (1|ID)	698.71	0.06
M5_J	PrePost ~ contingency*engagement + group + (1|ID)	702.25	0.01
M6_J	PrePost ~ contingency*group + engagement + (1|ID)	702.22	0.01
M7_J	PrePost ~ contingency+ group*engagement + (1|ID)	696.35	0.18
M8_J	PrePost ~ contingency*group + engagement*group + (1|ID)	698.53	0.06
M9_J	PrePost ~ contingency*engagement*group + (1|ID)	701.01	0.02

Fig. 4.14 – Model comparison for Judgment

The ANOVA test (*Fig. 4.15*) showed a main effect of contingency (p = 0.057). Participant rating of faces appears to increase for contingent faces and decrease for not contingent faces.

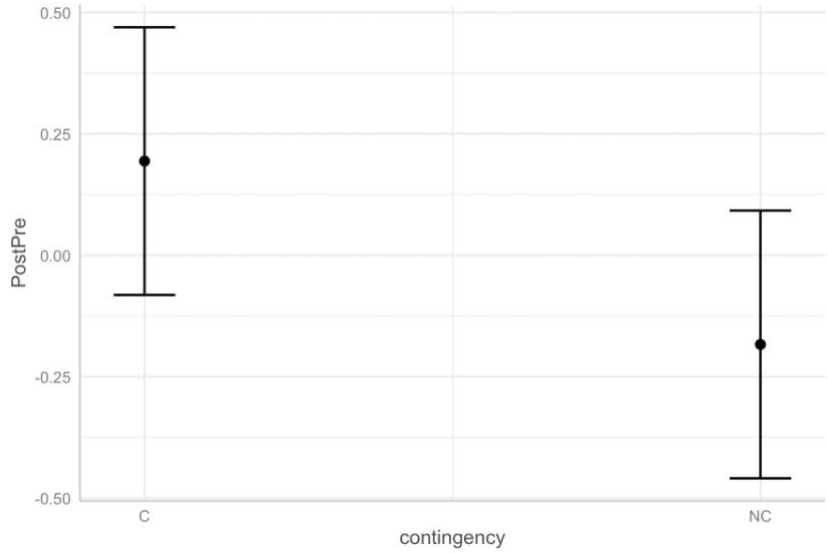

Fig. 4.15 – Contingency effects on pre-post judgment

Chapter V

DISCUSSION AND CONCLUSION

5.1 Discussion

The present work investigates the interactions within a social context, starting from the construct of Interpersonal Synchrony (IS). It is the spontaneous rhythmic and temporal coordination of actions, emotions, thoughts, and physiological process that occur between two or more people while interacting (Mayo & Gordon, 2020; Ackerman & Bargh, 2010). This mechanism has been widely investigated in the research filed, since it appears to be on the basis to build effective social interaction, communication, and cooperation, as well as promoting pro-social behaviours and attitude. It is also fundamental to develop social skills such as empathy, theory of mind, and self-regulation (Hove & Risen, 2009; Galbusera et al., 2019; Markova et al., 2019; Mayo & Gordon, 2020; Hu et al., 2022). Furthermore, the interpersonal entrainment occurs from the early life, within the parent-child interaction, and carries on for the whole life, in all the interpersonal interactions (Feldman et al., 2003; 2007).

All the positive effect and the impact in the social interactions of the Interpersonal Synchrony found in for the typical developing population, appear to be not as much descriptive of the impact on the atypical population. In particular, the Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder that present, as a core features, difficulties in social communication and social interaction (APA, 2013). Those difficulties can be seen in simple social element such as the eye contact, which appear atypical and reduced towards social stimuli (Farroni et al., 2002; 2007), as well as in more complex cognitive activities, such as joint attention (Vivanti et al., 2017). There are multiple theories that provide and explanation for this ASD peculiar characteristic: it might be due to a deficit in the Theory of Mind deficit (Baron-Cohen et al., 1985), which describe the ASD as “mind-blinded”. The Central Coherence Theory (Frith & Happé, 1994) suggest that the problem is linked to an impairment in the perception of the global viewpoint, while the deficit in the Executive Functions Theory (Militerni, 2015), point out a deficit in the planification, organization and control of actions, and in the problem solving, all fundamental in social environments. The Social Motivational Theory

(Chevallier et al., 2012) proposes the idea that the ASD are less attracted and find social stimuli as less rewarding, while the Social Brain approach (Johnson & Haan, 2015) focus on a possible impairment in the brain circuits that is activated in responses to the social stimuli.

The literature on the social atypicality of the ASD population investigated if there are atypicality also in the synchronization with others. From an overview of the literature, a general difficulty in the neural, physiological, and behavioural (motor and conversational) levels was found (Saxbe et al., 2017; Kruppa et al., 2020; McNaughton & Redcay, 2020).

We decided to focus on the Motor Interpersonal Synchrony level and to conduct a meta-analysis to understand if the published literature support a difference in the ability to get in-sync between the typical and the atypical (ASD) developing population. Our research question was: "*Do ASD (compared to TD) individuals manifest reduced interpersonal motor synchrony during social exchanges?*". We included 11 dyadic studies, with both typical and atypical groups participated, in order to compare the results. For the data analysis we calculated the effect size for each study and were used a Random-effects model to compare the results: this gives us the possibility to generalize the meta-analysis outcome.

The results suggest that there is medium effect, and therefore that there is a difference in the Motor Interpersonal Synchronization between the ASD and TD groups. In other words, the answer to our research question would be "*yes, ASD individuals manifest reduced motor IS during social exchanges*". However, the statistical results suggest that there is a high heterogeneity in the studies considered and in their effect size, which suggest that by including a much broader literature to this systematic review we could find a much stronger effects, as well as very small effect. The high heterogeneity in the study population might be due to the different measures for motor IS used. For example, a study measured the percentage of time the child perfectly synchronized his/her actions with the tester (in-sync) or not (out-of-sync) (Kaur et al., 2018); another study coded the number of pixel changes between adjacent frames (relative phase) to measure the bodily coordination with the experimenter (Fitzpatrick et al., 2013); or the motion energy of head, hand and trunk during a seated neuropsychological testing and natural conversation (Noel et al., 2018). Therefore, including studies with more similar measure

of interest might decrease the study heterogeneity. Furthermore, the standardized and very structured experimental environment need to be considered: the studies involved participants in dyadic tasks, which could not describe properly the behavioural response in a more ecological environment. Indeed, being in this kind of context might diminish the difficulties that ASD individuals would show in a daily life context, suggesting that the meta-analysis could be attenuated by this variable.

Another reason might be linked to the characteristics of the sample included in the papers. The participants age range went from the 4 years to the 45 years, so we cannot have a clear understanding of the Motor IS in children, adolescents or adults; instead, this meta-analysis gives an overview of the ASD VS TD population regardless the age. Furthermore, the ASD participants included in the studies usually didn't present a severe or moderate impairment and manifestation of symptoms. This might be a variable that modulate the ability to synchronize with others (Dowell et al., 2009; Kaur et al., 2018; Bloch et al., 2019): a higher severity of symptoms is linked to a higher difficulty in interacting with others and in get-in-sync with another person, and even more in synchronizing in more complex social environment. Consequently, studies with more severe ASD traits might provide evidence for higher reduction in the motor IS, compared to a TD group, thus a stronger effect. On the contrary, involving ASD individuals with a lighter symptomatology and with trained social skills might conduct to a very small effect.

Focusing on the meta-analysis results and on the reviewed literature on the Interpersonal Synchrony, we questioned whether there are some elements in the social interaction that might influence the synchronization process. We identified two components of the IS: the temporal contingency of the stimuli (responsiveness) and the social engagement (communicativeness). The first one refers to the temporal closeness between action and responses, which might facilitate the synchronization process as well as increasing the engagement process towards the stimuli. The engagement should be even stronger if there is a social stimulus that share a communicative behaviour, since it carries a motivating and rewarding value (Chevallier et al., 2012).

Our experimental paradigm was designed to investigate if and how those two components (contingency and engagement) would modulate the choices and the preference for the faces presented. Our first anticipated scenario was that the TD group would prefer the contingent and engaging faces, while the ASD group wouldn't show any

preference. Our second scenario was that the TD group would show no preference for the contingency responses, but choose more the engaging stimuli, while the ASD group would show no preference for the engaging VS non-engaging stimuli but choose more the contingent ones.

As for the choices the experimental results are consistent with our second scenario. Specifically, we found two effects: (i) an interaction effect of contingency and group, (ii) main effect of engagement. The TD didn't modulate their choices depending on the contingency condition, probably because they are used to non-contingent interaction and delays in the responses in the daily life. Therefore, they developed an expertise both for fast and contingent responses, and for slower and non-contingent ones. This is in line with the study by Klin and colleagues (2009), where they claimed that the typical developing population prefer more socially relevant signals to the temporal contingency. The ASD group, instead, chose more frequently the contingent faces: they give priority to the stimuli that provide a faster and temporally closer answers. This might be due to an intolerance for delays, both in the experimental condition (Klin et al., 2009) and in more ecological settings: indeed, many clinical interventions work on the development of the tolerance for pauses between a request and the answer (Ferguson et al., 2020; Gajić et al., 2021).

Another variable that influenced the choice was the engaging condition: all the participants preferred and chose more the engaging faces compared to the non-engaging ones. This variable had the same impact in the typical and the atypical group. Therefore, we can say that the engaging social stimuli presented were attractive and carried a high motivating value, which led the participant to choose those faces (Farroni et al., 2002; 2007; Chevallier et al., 2012). It's worth noticing that the stimuli presented appeared to be at the same time interesting enough to catch the attention, but simple enough not to be overwhelming or overstimulating, especially for the ASD group (Dunn, 2007).

We also investigated the reaction time (RT) to see if those two parameters would elicit faster or slower responses, however the results didn't show any significant effects. We only found that the reaction time decrease as age increases. This result is consistent with the literature; indeed, it has been widely documented the influence of the chronological age on the speed reaction during RT tasks. The RT across ages follow a U-shaped curve: the response is slower in infant and children, it becomes faster during

the adolescence and in the early-midlife, and slow down again in response to the aging process (Welford, 1988; Deary & Der, 2005; Bucsuházy & Semela, 2017).

Regarding the influence of the interaction part of our task on the preference and judgment (pre-post testing), we found that the contingency has just little influence of the judgment expressed by all participants. Indeed, the results showed that a trend is present, but this is not statistically significant. We can therefore say that the contingency could have an influence in the daily life, in motivating people to interact and engage with others, but more research is needed to this end.

5.2 Limits and future research

The present work's aim was to provide a further knowledge to the existing literature on Motor Interpersonal Synchrony and on two components of the synchronization process. However, a few limitations can be found, as well as suggestions to improve future research.

About the meta-analytic study, it included only 11 studies since the inclusion and exclusion criterion were very strict. The literature in this respect is thus quite at the beginning and the low numerosity of included works could have had an impact on the results. The heterogeneity of the studies and the multiple measures used in each one might have had an impact on the results as well. To improve those aspects, more studies need to be run with interacting human partners and considering both typical an atypical developing population. Ideally, there should be less variability among measures used to investigate motor IS. This would provide a wider group of studies that, if included in a meta-analysis, could clear the effects size of the motor IS difference between ASD and TD individuals within a social context.

To run the statistical analysis, we used the random-effects approach model, which allowed us to calculate the effect size by considering the high variability among studies. The small sample size of studies suggested that a fixed-effects approach would be more appropriate. However, this model assumes no variability between effects size, which is less plausible theoretically speaking, thus we decided to focus on the random effect. Further analysis should also include this approach.

The meta-analysis would have benefited from the possibility to include participant age and symptom severity as moderators; however, the small sample size did not allow us to perform this kind of analyses. Future research could therefor address this topic as well, investigating whether Motor IS in ASD compared to TD is modulated by age and symptom severity

As for the experimental paradigm, it constitutes a starting point for more complex future research. The interaction studied happen between a human being and a face on a screen, which is like an online interaction that can happen daily. Moreover, the stimuli used were quite simple, indeed the faces on the screen performed a simple action, which is turning their head. However, most of the interactions do not happen behind a screen and carry a higher complexity, thus it would be interesting to study the contingency and the engagement effects during more ecological tasks. This might show a stronger difference between the TD and the ASD groups.

The ASD sample of the experimental study included participants with a high variability of symptoms, thus our results are an overview of individual that represent a quite well the variability in the spectrum, with an exception for the severely impaired indivodials. We don't know if the severity of the condition interacts somehow with the temporal contingency and the engagement variable. Therefore, we suggest collecting a broader sample to allow the investigation of possible differences between severe, mild, and moderate symptomatology, as well as depicting an overview of the ASD responses that can be compared with a TD control group.

Another suggestion is to run the study with both human-like stimuli and objects, to investigate if the contingency and engaging variables have a role in both the animate and inanimate interaction and if the TD and the ASD groups shows differences in their preferences.

5.3 Clinical implications

Those findings on Motor Interpersonal Synchrony, on the ASD individuals' difficulties in aligning their behaviour with an interacting partner, and on the influence of the temporal contingency of stimuli and their communicative value can also have interesting implications in the clinical area. Indeed, this knowledge can be useful both in

the diagnostic process and in treatments and interventions. A lack of temporal binding (Brock et al., 2002) and synchronization might contribute to the inflexibility of behaviour, to the poor adaptation and to the significant social and communicative difficulties found in ASD individual. Therefore, during the assessment and the diagnostic process it could be interesting to investigate those aspects, both to understand if there are predictive behaviours for a further development of the ASD and for an early intervention.

The suggestion for the diagnostic area would be to consider the Motor Asynchrony as a diagnostic marker, and thus to evaluate the individual ability to align with another person with an animate object. Those communicative behaviour could be measured trough the motion analysis, the eye tracking, or the video tracking (Bloch et al., 2019). However, we recognize that this would require to have the instruments and enough time, which are rarely available in the clinical practice. Thus, the clinical observation remains fundamental to notice motor and behavioural atypical pattern in the synchronization and alignment with others.

As for the treatment, it could be important for the therapist to work on the behavioural alignment with the ASD individual they are treating. For example, working on the development the ability to coordinate movements and gestures, could help the understanding of communication signals coming from the interacting partner. As a consequence, there should be an improvement of the interpersonal interaction, at least on a non-verbal level (Bloch et al., 2019).

Some authors tested already if the inclusion of a work on the development of interpersonal synchronization have an impact on the social skills development in ASD toddlers and children. For example, Landa and colleagues, in 2010, proposed an intensive intervention involving toddlers from 21 to 33 months and their parents. Since it was a randomized control trial, one group followed the intervention program with the specific target on IS, while the other group had the same intervention without the module on IS. Toddlers were highly stimulated in order to engage them in imitative social interaction, in joint attention and in affect sharing. Results supported the positive impact of the IS intervention: toddlers showed a higher rate of imitative behaviours and eye contact, the abilities were generalized to unfamiliar contexts and maintained in the months following the treatment (Landa et al., 2010). It must be highlighted that parents had an active role; indeed, they were trained to elicit engaging and synchronized interaction in their children.

Involving a parent-training in the intervention, teaching them to display engaging behaviours and to stress the temporal contingency between the toddler's behaviour and their responses could have a positive cascading effect on the children's social abilities (Landa et al., 2010; Northrup et al., 2017).

5.4 Conclusion

Overall, this work provides information on the existing literature on Motor Interpersonal Synchrony, highlighting a deficit in this social ability in the ASD individuals, especially when involved in social contexts. Furthermore, we suggested that two variables that influence the Interpersonal Synchrony are the engagement and the temporal contingency. The research presented showed that both typically and atypically (ASD) developing individuals prefer engaging stimuli or individuals, probably because they carry a higher motivational value and appear as more interesting. The temporal closeness between action and responses, instead, seems to have a higher impact on the ASD population: they prefer rapid and contingent stimuli to slower and non-contingent ones. Those results give several suggestions for future research, and but also for the clinical practice: working on temporal contingency might provide benefits and improvements on the ability to align and behave in-synchrony with others, as therefore in the ASD social and communicative abilities.

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