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Cognitive-affective processes in interpersonal synchrony: behavioral and neural associations with borderline personality traits. Clinical implications in psychotherapy.

PhD Student: Gregorini Camilla (876167)

Supervisor: Prof.ssa Laura Parolin

Coordinator: Prof.ssa Simona Sacchi

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To my ‘secure base’

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Summary

Nowadays, the term “synchrony” is still complex to define and delimit. Different fields, such as social signal processing, computation neuroscience, and developmental psychology, have approached the phenomenon using various terms and modalities to describe and assess the interpersonal dependence of behaviors, emotions, and physiological patterns (Delaerche et al., 2012). However, a multidisciplinary approach is largely encouraged to study the processes that are the “pre-conditions” of synchrony. To fill this gap, this thesis explores how individual differences modulate the processes underpinning interpersonal coordination during synchronized interactions. Specifically, with “interpersonal synchrony,” we mean the individuals’ temporal coordination of actions during social interaction (Sebanz et al., 2006; Richardson et al., 2008) that we studied using a computational approach (Fairhurst et al., 2013; Van Der Steen & Keller, 2013). Furthermore, this thesis also explores the role of “staying in sync” within therapy in relation to the supposed potential association with the therapeutic interactive process (Koole & Tschacher, 2006).

In section one, we present a series of studies grounded within the theoretical clinical frameworks related to borderline personality disorder (BPD) while adopting an experimental approach. Specifically, we focus on the psychopathological role of high BPD traits resulting from a developmental trajectory embedded in environmental and biological interdependence. In this sense, Chapter 1 explores whether high BPD traits affect the ability to coordinate and synchronize with a variable adaptive partner and the emotional experience of the interaction. Our findings revealed that the high BPD traits were associated with higher behavioral asynchrony and variability even when the partner was moderately adaptive. Furthermore, those individuals reported a low perception of “feeling with” and a higher negative affect than those with low BPD traits. Such findings reveal that pathological cognitive and affective schemas might play a role in modulating interpersonal

synchrony and negative affect, suggesting higher impairments in emotional modulation in individuals with high BPD traits than low BPD traits. As an extension of these results, in Chapter 2, using the same behavioral task, we investigate whether self and other mental representational disturbances modulate mu rhythm during self and other synchronized interactions and the subjective experience. Partially in line with our hypothesis, we found that individuals with high BPD traits showed altered mu suppression at a specific component of mu rhythm (10 Hz) during all the conditions as a sign of reduced sensorimotor integration within the action-perception loop (Hari & Kujala, 2009). Unexpectedly, individuals with high BPD traits perceived higher cooperation at increasing the partner's adaptivity, suggesting alternative but coherent clinical interpretations. Then, to analyze the role of synchrony from a more "affective" perspective, Chapter 3 unfolds across three studies and builds on the knowledge that high BPD traits are associated with an untrustworthiness bias and higher emotional dysregulation when processing interpersonal stimuli. Consistent with that and partially in line with our hypotheses, we found a bidirectional link between trustworthiness and synchrony. However, contrary to our hypotheses, BPD traits did not modulate these associations but only the emotional experience.

Further, taking a slightly different perspective, in section two, we analyze the role of one specific type of "interactional synchrony"- the nonverbal synchrony (at behavioral and vocal levels) - within therapy resulting from a computational synchrony assessment. In this sense, we move toward the therapeutic setting to ascertain the effect of nonverbal synchrony at behavioral and vocal levels in psychotherapy. Chapter 4 describes a meta-analytic study exploring the relationship between nonverbal synchrony in association with the alliance and the therapeutic outcome. Our results revealed a significant association between nonverbal synchrony and alliance (mainly behavioral and alliance) but not with the therapeutic outcome. Further, the therapeutic approach did not moderate the associations.

Overall, our findings point out that high pathological personality features related to BPD significantly impact interpersonal stability during synchronized interactions and co-representing self and others during dyadic interaction. Furthermore, high interpersonal vulnerability has been found to hamper the emotional modulation of negative affect, extending previous findings. Then, consistent with the view that interpersonal synchrony could enhance trustworthiness and vice versa, we suppose that synchrony could be relevant during therapy. Along these lines, we will encourage future studies to extend such a multidisciplinary approach to increase our results, taking as an 'initial step' our conclusive idea that the "we-mode" - not only at the cognitive but also at the behavioral level - might be essential for establishing and sustaining the therapeutic alliance.

General introduction

General introduction

The starting point of social interaction

Social interaction has been considered as a "co-regulated coupling between at least two autonomous agents, where the co-regulation and the coupling mutually affect each other, constituting an autonomous, self-sustaining organization in the domain of relational dynamics and the autonomy of the agents involved is not destroyed" (De Jaegher et al., 2010). How does it happen? Social cognition abilities as individual blocks guide the social encounter. How people "understand others' actions in terms of intentions, emotions as well as understanding with others" (Frith, 2008) define the quality of how people can create a co-regulated pattern.

From a developmental perspective, such quality involves the mental representation of self and others and the cognitive and affective schemas that develop within the experience of mutual co-regulation since early interactions (Schore, 2013, 2014; Siegel, 2012). Bowlby (1969/1982) presented the 'attachment theory' as a new paradigm and theoretical framework for understanding the "infant's tie to primary caregivers," enhancing the evolutionary function of the attachment figure's availability and proximity in promoting safety and protection. The attachment system highlights the control dimension of the behaviors and "the attachment as the highest-level system that organizes them" (Bowlby, 1969; Waters & Sroufe, 1983). Specifically, the "secure base" phenomenon has been considered the highest organizational structure of the behaviors during bidirectional interactions mother-child. However, Bowlby (1969) recognized that the proximity depended on many different factors (i.e., contextual, infant's tiredness, illness) and, even more importantly, on the mother's availability and responsiveness (Bowlby, 1969). The seminal laboratory study of Ainsworth and colleagues was also oriented to go beyond the proximity-seeking and exploratory behaviors and capturing how well the infant managed the attachment-exploration balance across time (Ainsworth et al., 1978). Since then, the child's behavior in relation to the ‘other’ has been categorized as secure, insecure (avoidant-resistant), and disorganized-disoriented (Ainsworth et al., 1978; Main & Solomon, 1986). Furthermore, Bowlby (1969) identified that species-characteristic behaviors as “attachment behaviors” (smiling, crying, clinging, following, and sucking) may also be flexible and goal-directed (Bowlby, 1969). Specifically, through a continuous input and output process, behavior is a “set goal” and tends to reach a state of “goal corrected.” This encompasses behavioral systems structured in terms of biologically established set goals that are flexible and driven by internal working models (Bowlby, 1969). These “cognitive maps” will orient the mental representations and the emotional-interpersonal regulation being the lens and the social threads of relating with others. However, the importance of the infant’s confidence in the attachment figure’s accessibility and responsiveness is the basis for creating expectations about others in terms of “accessible and responsive” (Bowlby, 1969; Ainsworth et al., 1978). Those expectations are embedded into the child's representational model of his mother figure, which would lay the ground for the representation of the self in relation to the other.

Moreover, Bowlby (1973) presented the four stages of the development of child-mother attachment, emphasizing that the infant has behavioral equipment that consists of fixed action patterns that become organized together and linked to environmental stimulus situations under processes of learning that have become well-known through stimulus-response (Bowlby, 1973). Furthermore, the goal-corrected behavior onset with the ability to distinguish between means and ends and certainly hierarchical organizations of the behavior according to plans depend on means-ends distinctions and achieving the ability for “true intention.” However, achieving the ‘permanent of the object’ is necessary for a child’s attachment to specific discriminated figures (Ainsworth & Bowlby, 1991). Echoing Piaget (1936), the child begins to learn that there is a “consequence” between social cues: one environmental event is “a cue” that another environmental event will follow. In this sense, the ability to anticipate his mother’s actions and adjust his plans to his mother’s expected behavior would be the ground for reaching mutual reciprocity based on a "goal-corrected partnership" (Ainsworth & Bowlby, 1991). This would define the flexible hierarchical organization of the child's attachment behavior and his mother's reciprocal behavior implicated in the concept of 'plans.' Furthermore, in his "control-systems theory of behavior," affect and emotions are "appraising processes" (Bowlby1969/1973). According to this view, the input is compared to internal "set-points," and behaviors are selected in preference to others because of this comparison. That has been "the significant step" (Ainsworth et al., 1978) since the mechanisms and the context sensitivity of attachment responses have been considered central to controlling behavior. The ability to control such an emotional pathway is rooted in the constant interaction with the other, in the experience of mutual co-regulation within beliefs and expectations about the other as available and responsive (Ainsworth & Bowlby, 1991; Bowlby, 1988; Brazelton et al., 1975). From a psychopathological perspective, when developmental hallmarks and the environmental caregiver in terms of the internal organization of affects and responses drive to an atypical trajectory, maladaptive individual differences might develop and structure the building blocks of adult behavior and personality (Meyer et al., 2001; Mikulincer & Shaver, 2007).

The development of the "social self"

According to the primary intersubjectivity view (Stern, 1985; Meltzoff, 1985/2002; Trevarthen, 1979), the development of the Self occurs in five stages: physical, social, teleological, intentional, and representational. In this framework, actions concern two types of relationships: the self as a physical entity equipped with a force that is the source of the action and the self as an agent whose actions produce changes in the surrounding environment. From the self as a "physical agent" that develops within the interactive context and through action to the self as a "social agent," the subject learns the representation of distant causal effects that can be produced by species-specific communicative manifestations (Neisser, 1988). From 8-9 months, children begin to differentiate actions from their existences and present actions as *means* that serve to produce desired states

(Tomasello, 1999). Here, the self is a teleological agent (Csiba & Gergely, 1998; Leslie, 1994) and selects the most effective alternative actions to reach a goal among the alternatives. At 2 years, the self begins to develop as an intentional agent up to the representation of beliefs (Wimmer & Perner, 1983). At this stage, the self reaches a representational agent, and actions are guided by representations of intentional mental states (desires and beliefs). In this sense, a certain internal organization is created, and an autobiographical self is reached. Notably, it is possible to distinguish different positions within the phase of the agent and social self. The "strong intersubjective position" observes that from birth, there are innate mechanisms that allow the mind to attribute the mental states of others during contingent interactions and which are recognizable on an introspective level and "shared" (Trevarthen, 1979). Meltzoff and Gopnik recognized that the child can imitate the gestures of others due to an inherent ability to detect correspondences between his own and other actions (Meltzoff & Gopnik, 1993). Since birth, child can translate environmental stimuli through *"transmodal correspondences"* into internal states and find matches. Along this view, this ability underpins the ability to create a shared meaning and a feeling of being "on the same wavelength" and "you are with me" (Meltzoff, 2007). Furthermore, this is based on the ability to create similarities. Specifically, the sense of self does not result from the interaction with the other mediated by affection and the quality of responsiveness but from the perception of one's movements in the actions and gestures of others and from the proprioceptive experience of one's actions as like his/her own. However, this theory analyzes the child's expectations concerning sequences of actions organized procedurally and underlying how, within this process, there is a form of mirroring at the level of actions, which recalls the concept activation of mirror neurons (Gallese & Goldman, 1998; Rizzolatti & Craighero, 2004). During that process, the child can observe the actions of others and recreate the same actions in themselves. The capacity to identify that 'you are like me, and I am like you' contributes to the awareness of being known by the other and being together. But how does this process happen?

According to Trevarthen (1979), this occurs through "empathic consciousness" within a dyadic "conversational mind," which enables the child to establish empathic contact without the use of language (Trevarthen, 1979). According to the author, behaviors are contingent on a temporal level through imitation that allows the group members to mirror each other and, in turn, create a mutual resonance. According to his view, correspondences regulate interpersonal contacts and internal states by developing intersubjective processes as preverbal and dialogic phenomena (Trevarthen & Aitken, 2001). Similarly, Stern (1985) identifies the process of mental origin with the interactive process, and the interpersonal correspondences are a reciprocal dyadic process in which there is a constant interactive model based on a bidirectional influential process. Stern underlines how a given behavior's rhythm, form, and activation state are central within the bidirectional process. This leads to a change in the interaction shared by the other and supported by a two-way action process. This recalls the 'affective attunement' that unfolds within as a series of transmodal correspondences in the internal rhythm and form of behavior. Gergely and Watson (1996; 1999) slightly deviate from this approach, proposing the Social Biofeedback Model of Affect-Mirroring (Gergely & Watson, 1996, 1999). According to the model, the infant's ability to recognize his/her internal states and the sharing is a developmental outcome. During "marked mirroring interactions" (Fonagy & Target, 2002; Gergely & Watson, 1996), the attachment figure "marks" her referential emotion displays to signal the generalizability of knowledge and effectively instructs the infant about his/her own subjective experience (Fonagy et al., 2007). Gergely (2007) defined that the marked mother's response (exaggerated version of the affect) is accompanied by ostensive cues (mother's gaze, head slight tilting of her head toward him, her direct eye contact, the "motherese" intonation, and the calling of the infant's name) that serves to mitigate the potentially arousing effect of direct imitation (e.g., the mother crying when the infant cries), while simultaneously making salient to the infant central aspects of his internal experience (Gergely, 2007). Furthermore, accurate affective mirroring is a pre-conditional factor for learning about the dispositional states of others in terms of intentional and affective states of the self that guide the building of stable and differentiated mental representations of self and others. The mirroring might be the "intersubjectivity glue" through which the child develops a second-order symbolic representational system for his mind states with a preference for *high-but-imperfect-contingences* (Jaffe et al., 2001; Beebe & Lachmann, 2013; Gergely, 2007). Furthermore, the mirrored experience is relevant for forming the *as-if* mode of communication expressed in pretend play (Fonagy & Target, 1997) that protects from a "psychic equivalence state" (Fonagy & Luyten, 2009). In this sense, mirroring is a state of resonance and implicit representation of the child's emotional states that the mother, being aware, returns to the child in a contained and non-frightening way and, in turn, sustaining social knowledge (Fonagy et al., 2002; Winnicott, 1971). In this sense, the intersubjective space builds through the interdependence of self-regulation and interactive regulation processes that generate patterns in the child's mind as the 'implicit relational knowledge' (Lyons-Ruth, 1998).

The interactive contingency as the early coordination

From a complementary intersubjective perspective, mutual bidirectional regulation relies upon the ability of each partner to identify when the other's behavior is contingent on their actions and vice versa (Beebe & Lachmann, 2013). This enhances the main role of reciprocal regulation that involves the coordination of affects, attention, spatial orientation, and behavior since early relationships whereby mutual regulation becomes a "primary organizing principle of every form of communication" and child development (Beebe & Lachmann, 2013). Contingency processes become central to the development of social expectations. Expectations of action sequences are translated into pre-symbolic procedural representations or models of "how interactions proceed" (Stern, 1985; Beebe & Lachmann, 2002, p.75). Specifically, the interactive contingency refers to the "continuous adaptations of one individual to modify the behavior of the other," and "a contingency score" reflects the degree of interpersonal coordination mother-infant. Moreover, the term "self-contingency" or "auto-contingency" was related to "adjustments in the individual's behavior that are related to previous behavior" (Beebe & Lachmann, 2013). Along this line, the authors introduced the term "interactive regulation" as a complementary term to interactive contingency since the degree of reciprocal contingent coordination influences the child's ability to monitor, process, and regulate their own and other behaviors and emotional states (Beebe & Lachmann, 2013). Empirical studies showed that children between 6 and 12 months could identify the slight change in the contingency structure of the interaction and reacted with displays of dissatisfaction and negative affect to the loss of the maternal contingency (Murray & Trevarthen, 1986).

However, there are different degrees of interactive contingency, and what was observed by Jaffe and colleagues is that intermediate levels were optimal for secure attachment while low or too-high levels were associated with insecure types of attachment (Jaffe et al., 2001). Along this vein, Beebe and Lachmann observed that high levels were excessive suggesting that those levels made the interaction more predictable but also along with excessive monitoring and dyadic vigilance that in turn hamper the harmony and the interactive co-regulation (Beebe & Lachmann, 2013). Further, a low level was associated with an inhibition of monitoring or a withdrawal where each partner was relatively "alone" in the presence of the other. In addition, an intermediate level was related to uncertainty, initiative, and flexibility. Such a level was linked to a proper experience of contingency and correspondence and was optimal for developing a secure attachment (Beebe & Lachmann, 2013). An optimal level of contingency could have favored a good development of regulatory capacity and modulation of affect. In this sense, maternal responsiveness and the quality of the emotional response to the child that is not perfectly contingent but *high-but-imperfect* has been considered important for communication and emotional co-regulation (Jaffe et al., 2001; Stern, 1985). Along this framework, the predictability of behavior and the contingency of responses reduce uncertainty about 'what will occur next' and generate a sense of 'being' and 'acting' in the subject during the interaction (Meltzoff, 2007). Expectancy patterns are formed, and responsiveness can be experienced, leading to secure attachment relationships and 'secure' mental representation.

Which mechanisms underlie interpersonal coordination?

According to Bernieri and Rosenthal, interpersonal coordination is “the degree to which the behaviors in an interaction are non-random, patterned, or synchronized in both timing and form” (Bernieri & Rosenthal, 1991a). Bernieri and Rosenthal (1991) identified three components of synchrony: interaction rhythms, simultaneous movement, and behavioral meshing. From the perspective of “joint action” research, when acting together, our brains and bodies are no longer isolated but immersed in an environment with the other person, becoming a coupled unit through a continuous moment-to-moment mutual adaptation of our actions and the actions of the other (Sebanz et al., 2006). This generates a set of inter- and intra-personal coupling modalities that create bonds and facilitate successful interactions (Konvalinka et al., 2012). However, focusing on the mechanisms that allow coordination to be established is crucial.

Coordinating one’s actions with others seems to require some interlocking of individual behaviors, motor commands, action plans, perceptions, or intentions. In this sense, interpersonal coordination concerns a group of mechanisms related to mentally representing the actions, such as in joint action goals, task co-representation, and monitoring the own and interaction partner’s actions (Vesper et al., 2017). The “joint action goals mechanism” concerns the ability to plan, monitor the action, and co-represent the self and other actions when people are involved in the same task. Specifically, monitoring the other actions in terms of anticipating and temporally aligning the action to the other's behavior is the main cognitive process that drives coordination and, in turn, enables interpersonal synchrony to emerge (Keller et al., 2016; Novembre et al., 2012). For example, “when we move a sofa together with someone, individuals need to predict what the other is going to do next to adapt their action and facilitate coordination” (Vesper et al., 2017). In addition, a relevant complementary mechanism in this context is the sensorimotor prediction related to another group of mechanisms called “sharing of sensorimotor information.” The sensorimotor prediction relies on the individual ability to plan their motor and goals (forward model) along with the ability to mentally represent the other's actions (Sahaï et al., 2017; Van Der Steen & Keller, 2013; Vesper et al., 2017). Such a process has been considered as a mechanism that echoes the feeling of "like me" (Meltzoff, 2007), resembling the activity of the mirror neuron system (Rizzolatti et al., 2001; Rizzolatti & Sinigaglia, 2010). In this sense, the ability to co-represent self and other actions leads to improved coordination, and then interpersonal synchrony could be positively affected through a mutual adaptation strategy (Heggli, Cabral, et al., 2019). Additionally, the "coordination smoothers" have been considered as mechanisms that support and facilitate coordination, modifying one's behavior to make it easier for the other to predict the next action (Vesper et al., 2010). Flexibility and less variability improved coordination, facilitating interpersonal synchrony to emerge (Skewes et al., 2015; Vesper et al., 2013). All those processes drive the behavioral dynamics, defining the mutual regulation and leading to a specific degree of mutual coupling as an index of interpersonal synchrony.

The many faces of interpersonal synchrony

Recently, Koban and colleagues tried to distinguish between coordination and interpersonal synchrony, suggesting that interpersonal coordination could be considered as the "mutual behavioral or physiological adjustments in social interactions" while synchronization is more specifically defined as the "adjustment of rhythms of self-sustained periodic oscillators" (Koban et al., 2019). However, from a wider perspective, the interpersonal coordination processes as a kind of "know-how" (De Jaegher et al., 2010) are the mechanisms that occur during synchrony, defining the quality of the social interaction (Delaherche et al., 2012). In this sense, interpersonal synchrony has been considered "a specific class of coordinated actions" (Cirelli, 2018), which drives the interaction and relies on the interplay of several individual mechanisms that co-occur and create a mutual interactive harmony. The dimension of time is the distinctive feature of synchrony that immediately sheds light on how the phenomenon can be differentiated, for instance, by the "chameleon effect" or the "mimicry" (Lakin et al., 2003).

Interpersonal synchrony can be measured in many interactive contexts (cooperative activities, joint action, turn-taking, natural conversation, and nonverbal interaction) at the motor, verbal, physiological, and neural levels. Motor synchrony concerns the ability to align the actions with the other interaction partner and shape a mutual alignment through the ability to predict and anticipate the other actions (Schmidt & O'Brien, 1997). This modality of synchrony could be detected through experiments such as tapping, drumming, clapping, marching, during sports, or just cooking together. It can be intentional (Reddish et al., 2013) or spontaneous (van Ulzen et al., 2008). Notably, this type of synchrony could be measured in terms of sensorimotor synchrony using simulations or computational methods creating virtual partners (Repp, 2005), allowing the use of several behavioral manipulations during the interaction (Fairhurst et al., 2013, 2014; Konvalinka et al., 2010; Mills et al., 2019). Moreover, interpersonal synchrony could be measured within a conversation (Church et al., 2014). That is called vocal or conversational synchrony, and it is involved in less structured tasks where vocal alignment and turn-taking are measured (Aafjes-van Doorn et al., 2020; Aafjes-van Doorn & Müller-Frommeyer, 2020). Another possible way to study the phenomenon is at a physiological level that entails the alignment of nervous system activity, parasympathetic nervous system activity, or adrenocortical activity between interacting partners, and it is associated with empathy and rapport (Palumbo et al., 2017). Relevant studies (Bar-Kalifa et al., 2023; Konvalinka et al., 2011; Palmieri et al., 2021) measured physiological synchrony, including electrodermal synchrony, heart rate synchrony, and cortisol synchrony in different scenarios such as face-to-face and therapy. Then, neural synchrony refers to the alignment of brain activity between interacting individuals (Dumas et al., 2011; Mu et al., 2018). Different paradigms, such as cooperative task, drumming, mirror-game, joint attention task, and turn-taking verbal interaction, have been used to measure the hyper-scanning activity using EEG, MEG, fNIRS, and fMRI (i.e., Babiloni et al., 2007; Czeszumski et al., 2020; Dumas, Laroche, et al., 2014; Konvalinka et al., 2014; Konvalinka & Roepstorff, 2012). Nowadays, research is approaching interpersonal synchrony in relation to clinical populations such as autism spectrum disorder (McNaughton & Redcay, 2020) and schizophrenia (Pan & Cheng, 2020). However, more research is needed to explore better mechanisms that sustain and underlie interpersonal synchrony in psychopathology and in clinical populations.

Why does "staying in sync" matter?

Consistent with the temporal and organizational features of the dyadic interaction, synchrony is like "a time-bound" and a co-regulatory lived experience within attachment relationships (Feldman, 2007). The synchronous communication flow at behavioral, affective, and physiological levels facilitates interaction, promotes openness between mother and child, and enhances the degree of "presence in a gathering" during face-to-face interaction (Feldman, 2003; Trevarthen & Aitken, 2001). Empirical findings showed that affective communication during first relationships is one of the key factors in secure mother-infant attachment relationships (Beebe et al., 2012; Feldman, 2012a; Isabella & Belsky, 1991). According to the biobehavioral synchrony model, shared moments of interactions between parent-infant accelerate the maturation of the infant's relational skills and growth, providing essential environmental inputs for the development of self-regulation and social adaptation (Feldman, 2003). In turn, the intensity of these moments requires the external regulatory framework afforded by the organization of the temporal parameters of the interactive exchanges and the maternal mirroring (Beebe & Lachmann, 1988) as an antecedent to developing secure attachment (Ainsworth et al., 1978; Belsky, 1984; Jaffe et al., 2001).

Since the early years, interpersonal synchrony has played a central role in developing social cognition processes and behavior. Studies investigated the role of early social preferences and prosocial behaviors in synchronous or asynchronous interactions. Since 12 months, infants show an early social preference for synchronous interaction (Tunçgenç et al., 2015). Moreover, infants of 14 months showed more helping behaviors in synchronous conditions vs. asynchronous (Warneken & Tomasello, 2006, 2007). Cirelli and colleagues found that children at 14 months old helped the 'friend' of a synchronous partner more than the 'friend' and an asynchronous partner (Cirelli et al., 2016). Then, children at 4 years of age showed more helpful behaviors in synchronous conditions than in asynchronous conditions. The authors also found that during synchrony vs. asynchrony, more mutual patterns (smiles and eye contact) could be detected among peers (Kirschner & Tomasello, 2010; Tunçgenç & Cohen, 2018). At 8 years old, children who tapped in synchrony with a peer rate that child as more similar and socially close to them than an asynchronously-tapping peer (Rabinowitch & Knafo-Noam, 2015). Interestingly, in one study, the synchrony inter-group could reduce negative out-group biases in a minimal group, suggesting that synchrony could be a direct feature that increases feeling more bonded and obstacle in-group favoritism and outgroup negative biases (Tunçgenç & Cohen, 2016). But how does synchrony lead to positive feelings? There are different hypotheses.

First, synchrony could enhance self-similarity and, in turn, promote affiliation and empathy. For instance, relevant studies have linked synchrony to a wide range of social-affective phenomena that sustain prosocial behavior, including increased affiliation and liking towards group members (Hove & Risen, 2009; Tarr et al., 2015, 2016), greater levels of subjective rapport (Miles et al., 2009, 2010) and feelings of social connectedness amongst group members (Lumsden et al., 2014). Furthermore, evidence for synchrony's prosocial effects was reported by Wiltermuth and Heath through three different studies (Wiltermuth & Heath, 2009). In one experimental study, participants walked around campus together, and in another study, they sang and moved cups. The investigators varied levels of synchrony in both studies. They found synchrony increased donations in a subsequent coordination game (third study) involving trust and a public goods game requiring individual sacrifice for group benefit. Valdesolo and colleagues found that swinging in synchrony enhanced individuals' perceptual sensitivity to other entities' movement, thereby increasing their success in a subsequent joint-action task (Valdesolo et al., 2010). Notably, such finding has also received substantial support in subsequent studies where cooperation seemed to increase trust and prosocial feelings (Launay et al., 2016; Reddish et al., 2013). In this sense, synchrony fosters social cohesion and improves the ability to direct cooperative motives functionally.

Second, a mechanism of person perception could be implicated. For instance, Macrae and colleagues argued that a social allocation of attention during synchronous action affects positive social outcomes through greater attention to and processing of the actions of group members (Macrae et al., 2008), which then allows group members to translate subjective feelings of social cohesion into joint action (Miles et al., 2010; Valdesolo et al., 2010). Similarly, Reddish and colleagues found that synchronous actions, when combined with shared goals, enhance cooperative expectations and cooperative behaviors (Reddish et al., 2013). In this sense, synchrony towards a common goal might rehearse cooperation, which enables people to predict each other's actions. However, *sensitivity* to the movements of another combined with the ability to generate complementary actions at the appropriate time constitutes the essential components required for synchronizing action (Richardson et al., 2007; Schmidt & O'Brien, 1997; Sebanz et al., 2006).

A recent metanalysis by Mogan and colleagues found that synchrony ($k = 42$) increases prosocial behaviors ($r = 0.28$), enhances perceived social bonding ($r = 0.17$), improves social cognition ($r = 0.17$), and increases positive affect ($r = 0.11$). Then, synchrony's effect on prosocial behaviors and positive affect increases as group size increases but not social bonding or social cognition.

Third, considering that synchrony can influence the release of endorphins (E. E. A. Cohen et al., 2010; Sullivan & Blacker, 2017) and oxytocin (Gebauer et al., 2016), a neurohormonal hypothesis has been considered. Specifically, Cirelli (2018) suggested that the release of endorphins may underlie the affiliative consequences of synchronous movements as well as the intranasal oxytocin that improves behavioral synchrony and inter-brain synchrony (Cirelli, 2018). Since oxytocin is also released during parent-infant interactions (Feldman, 2012b, 2015), or when falling in love (Schneiderman et al., 2012), interpersonal synchrony may play a central role in facilitating attachment relationships through the release of oxytocin.

These findings sustain the view that interpersonal synchrony is a phenomenon that "comes together" (Koban et al., 2019), and it seems to play a central role since early relationships (Feldman, 2006). However, more studies are needed to investigate how and why synchrony could lead to positive feelings during social interaction. Then, an open question is also to investigate how the role of psychopathological features could modulate affiliation and prosocial behaviors within synchronized interactions.

The behavioral patterns of interpersonal synchrony

The ability to move in a "time-locked fashion" with the other (Cirelli, 2018) and the central role of the "dynamicity and reciprocal adaptation of the temporal structure of behaviors" have been pointed out as the main core interactive features that lead to interpersonal synchrony (Delaherche et al., 2012). Kelso and his students began to explore how the behavioral patterns associated with coordinated rhythmic limb movements can be manipulated as representing the dynamics of periodic attractors or limit cycles (Scott Kelso et al., 1981). According to the coupled-oscillators model (Haken et al., 1985), pioneering studies (Schmidt et al., 1990;Schmidt & O'Brien, 1997; Scott Kelso et al., 1981) have identified that during the dynamic oscillations of movements, speech, or feelings, interpersonal or interactional synchrony could emerge resulting from *intended* and *unintended* coordination mechanism. The coordination processes have been defined as *intended* when two or more people coordinate their biological rhythms together towards a common goal constrained by the explicit intention to coordinate (playing in a symphony orchestra or dancing together) (Reddish et al., 2013). Here we will focus on the *unintended* coordination that is an implicit property of the interaction that emerges from the dyadic interaction spontaneously and becomes entrained through different behavioral modalities. In this sense, two dominant modes of synchrony (in-phase and anti-phase) have been detected: in-phase (0°) (meaning that the actions of each individual are at equivalent points of the movement cycle) or anti-phase (180°) (when everyone's actions are at opposite points of the movement cycle). Specifically, Schmidt and O'Brien analyzed the interpersonal coordination of leg oscillation (Schmidt & O'Brien, 1990) and then pendulum swinging (Schmidt & O'Brien, 1997). The authors explored spontaneous coordination during visual or non-visual conditions, asking participants to coordinate with no direct instructions to synchronize. The results suggested a combination of in-phase and anti-phase attractive states, suggesting synchrony's dynamic nature. Further, Richardson and colleagues observed unintentional and intentional entrainment in individuals rocking in chairs side by side (Richardson et al., 2007). However, when instructed to keep rocking at their most comfortable frequency, they still showed a preponderance of in-phase relationships, at least when they looked at each other. Notably, when they had to rely on peripheral vision, the tendency to entrain unintentionally was very weak, whereas intentional entrainment in another condition was quite successful. Using a similar paradigm, Coey and colleagues investigated unintentional interpersonal entrainment when each participant swung two pendulums in phase or in antiphase (Coey et al., 2011). Regardless of the participants' intrapersonal coordination mode, intermittent in-phase coordination occurred when the participants' coordination modes were congruent with each other, and to a lesser extent when they were incongruent. Spontaneous entrainment via visual contact was observed while participants who carried out periodic finger movements at their preferred frequency required most participants to deviate from their preferred frequency (Oullier et al., 2008). When participants were subsequently instructed to close their eyes, they tended to stay close to their adapted frequency rather than returning to their preferred frequency. The authors attributed this persistence to social factors by simply continuing the adapted tempo. Besides the effect on movement tempo, visual information also facilitated spontaneous entrainment of interpersonal arm movements in the uninstructed direction, when participants deliberately moved in phase with each other but in orthogonal directions (one horizontally, the other vertically) (Richardson et al., 2008). These findings suggest that spontaneous synchrony of movements becomes entrained through different behavioral modalities and two dominant modes of synchrony: in-phase and anti-phase. Specific paradigms such as finger tapping have been adapted in the experimental field to study interpersonal synchrony within human-virtual partner (computer) interactions. Kelso and colleagues asked participants to tap their fingers in-phase (i.e., a 0° relative phase relationship, whereby the actions of each individual are at equivalent points of the movement cycle) with an animated finger visible on a screen, which in turn reacted to the participant's movements according to a coupled-oscillators model (Haken et al., 1985), thus simulating a virtual partner (Kelso et al., 2009). As predicted by the model, in-phase and anti-phase states emerge spontaneously and with a certain stability even though they were instructed to move in synchrony. However, even if they interacted in an apparent spontaneous way that fluctuated between synchrony or "out of synchrony," their movements became "entrained" during the interactive exchange. Since then, the study of interpersonal coordination and synchrony has started to move towards adopting the finger-tapping paradigm.

The finger tapping study: what occurs during tapping?

Finger tapping has been introduced to investigate the influence of the behavior of a responsive partner that varies the degree of adaptation during synchronized interaction (Repp & Keller, 2008). In this sense, the subjects were asked to synchronize themselves with the stimulus to reach a specific interactive coupling. During this task, a particular type of interpersonal synchrony emerged: sensorimotor synchrony (SMS) which is "the temporal coordination of an action with a predictable external event, an external rhythm" (Pressing, 1999; Repp, 2005). SMS relies upon some cognitive processes: temporal adaptation and anticipation (Repp & Keller, 2008; Repp & Su, 2013). Furthermore, two main theoretical approaches to SMS can be distinguished: dynamic systems theory and information-processing theory. Dynamical systems theory (Clark & Phillips, 1993) has been considered one of the three roots from which social coordination is hypothesized to arise. In this sense, social coordination is affected by the natural and innate ability to modulate behavior's directionality and mutual influence during social interaction, creating synergy (see Kelso, 2009). Moreover, the accuracy of the SMS varies as a function of the phase synchronization of movement oscillations with respect to the sequence of the external stimulus, which is defined as "interactive coupling" (Repp, 2005).

Additionally, a second relevant approach is the information processing theory (Repp, 2005), which explains the processes that allow different modalities of synchrony to emerge. In this sense, this theory defines the presence of a timekeeper and different sources of variability that can occur during the interaction. Moreover, the cognitive processes of anticipation and adaptation are modulated based on two error corrections (phase and period correction), which counterbalances these effects of variability and, therefore, contributes to maintaining synchrony with the external sequence (Mates, 1994; Semjen et al., 1998; Vorberg & Wing, 1996). The phase correction (alpha) is a local adjustment, while the period correction has a cumulative effect on the setting of the timekeeper, leading to tempo drift. In this sense, both errors are necessary during SMS, and because of this combination, the timing of the next tap is adjusted based on a percentage of the asynchrony (Kelso et al., 2009; Repp & Keller, 2008). In this context, the behavior could be interpreted as the result of cognitive control of some errors (differs from the regulation of the action or planning the action) and other mathematical features related to a precise analysis of what sustains the SMS to emerge. Moreover, the adaptation process is a central process during the interaction in support of the SMS as it allows the adoption of a certain interactive flexibility with respect to the variability that could accumulate in the different interactive moments. These mechanisms make it obvious that if those were not present at some level during the interaction, our interactions would be characterized by asynchrony, phase drift, and a general loss of synchrony (Dumas & Fairhurst, 2021; Konvalinka et al., 2023). Furthermore, the ability to anticipate others' actions requires "the capacity to extract structural regularities from ongoing events in the environment and to use this information as a basis for generating online predictions about the future" (Repp, 2005). In this sense, these small asynchronies indicate that a high level of temporal precision is related to the predictive mechanisms of SMS. Several research studies focused on the abilities of participants to tap along in synchrony with pacing stimuli that contain gradual tempo changes (i.e, Konvalinka et al., 2010; Mathias et al., 2020; Pecenka & Keller, 2009, 2011). However, the role of the individual differences in modulating such interactive processes remains largely unexplored.

The computational approach to study sensorimotor synchrony

During tapping, participants produce simple movements (finger taps) in time with external events (i.e., auditory stimulus, visual stimuli) that might vary in relation to temporal characteristics. Firstly, studies analyzed the participants' synchronization with a pacing sequence (isochronous or perturbated systematically) interacting with a non-adaptive partner (Repp, 2005). In this case, the coupling was unidirectional since the participants were asked to synchronize with the unresponsive pacing sequence. This approach was found to be not so informative about the mechanisms of social coordination since no mutual dynamics or adaptation processes could be detected. So, authors (Kelso et al., 2009; Repp & Keller, 2008) began to use experiments of human-virtual partner interaction with the use of simulations to examine the observed behavior of SMS and its underlying mechanisms. In fact, interactions with an auditory adaptive virtual partner or with a visual virtual partner (Haken et al., 1985) involved participants tapping in time with a computer-controlled pacing signal that simulated the potential behavior of a human partner by adapting to the participant's tap timing varying its degrees. The behavioral accuracy of the performance is the timing error—the asynchrony—between the occurrence of the action (tap and the tone) and the pacing event, which is called "negative mean asynchrony" (Aschersleben, 2002). The precision of the performance is the variability of asynchronies (i.e., an inverse index of the strength of sensorimotor coupling) and the variability of the intervals between consecutive movements (i.e., an inverse index of stability in tapping tempo) (see Repp, 2005; Repp and Su, 2013). Prediction and tracking tendencies can account for how accurately and precisely an individual synchronized with computer-controlled pacing sequences and how well the participants are able to synchrony with one another. In line with this theoretical context of information- processing, Van der Steen and Keller (2013) proposed a model "the ADaptation and

Anticipation Model (ADAM)" (Figure 1), to provide a better explanation of the role of anticipation and the adaptation mechanisms: how they are linked to and how they influence each other (Van Der Steen & Keller, 2013). The authors proposed that paired forward and inverse models are employed during a social interaction to simulate one's and others' actions. This coupling facilitates the SMS by allowing potential errors in timing to be anticipated and corrected before they occur (Keller & Repp, 2008; Repp & Keller, 2008). During some paradigms, such as finger tapping or drumming tasks, the predicted tap-time-interval of the participant is compared with the precited tone interval of the partner in a "joint internal model". This latter controls and regulates the balance of "self-other integration" and "segregation" therefore allows goals at the individual (intrapersonal) and group (interpersonal) levels to be pursued simultaneously (i.e., Heggli et al., 2019; Keller et al., 2016). According to ADAM, if the error between the anticipation and the adaptation falls within a pre-defined moment, the interaction goes on, and the tone will be carried out; if not the sound will refer to the default mechanism and return at the default tempo. However, an open question is how the effects observed in computer simulations – that is when the computer is programmed to interact with a typical human behavior – might be generalized to situations that involve the interaction between ADAM and live human partners. For instance, this setup could explore the social aspects of SMS during dyadic interaction, how the participants interact with a partner adaptive, and the role of the individual differences. In this sense, several studies (Ciardo et al., 2023; Konvalinka et al., 2010; Mills et al., 2015, 2019) pointed out the need for more research to investigate the role of individual differences in this context. This could feed into how the features of interpersonal functioning could be implicated during interpersonal coordination and synchronized interaction.

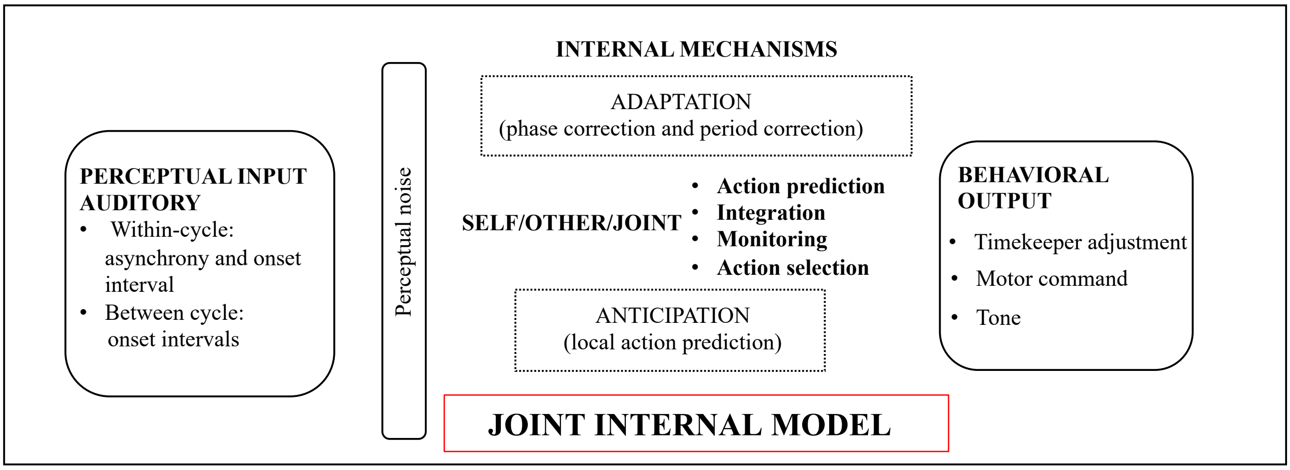


Figure 1. ADapatation and Anticipation Model (ADAM)

Some relevant evidence of human-computer interaction

Relevant studies examined the SMS during coupled or uncoupled interactions with different interactive partners. For instance, Konvalinka and colleagues were the first to study interpersonal synchrony during tapping in synchrony with a non-visual partner (Konvalinka et al., 2010). Paired participants were seated in separate rooms and started synchronizing with the same metronome. After a certain number of taps, the metronome stopped, and participants continued tapping in three conditions: with auditory feedback from their own taps only (no coupling), with auditory feedback from one participant's taps (unidirectional coupling), or with auditory feedback from each other's taps (bidirectional coupling). The results showed that bidirectionally coupled participants mutually adjusted their inter-tap intervals (ITIs), which was reflected in a negative lag-0 and a positive lag-1 cross-correlation of ITIs, without any evidence of a leader–follower relationship. In the unidirectional-coupling condition, the follower (who heard the leader's taps) tended to track the leader's ITIs at a lag of 1. The authors concluded that two coupled tappers formed an interactive unit of two "hyper-followers" that coincided with a continuous mutual adaptation. Another similar finding was presented in the study by Nowick and colleagues but here the authors found that mutual adaptation was characterized by temporal assimilation rather than by a compensation process whereby individuals correct each other's timing errors (Nowicki et al., 2013). More recently, studies (Fairhurst et al., 2013, 2014; Mills et al., 2019) explored SMS during an interaction with a variable adaptive partner that varied its level of adaptation and implemented a degree of phase correction or period correction to reduce asynchrony. In line with Repp and Keller, studies showed more synchrony and stability in a range that is the optimal range of adaptation (0.25 - 0.50) (Repp & Keller, 2008).

Moreover, this range has been perceived as a "like me" (Meltzoff, 2007) and seems to increase interpersonal synchrony and enhance the integration between self and other representations to reach 'we mode' (Heggli, Cabral, et al., 2019; Keller et al., 2016; Kourtis et al., 2019). Based on these previous finger-tapping studies, a recent model allows for studying interpersonal dynamics during tapping (Heggli et al., 2019) and describes the different coupling strengths between two actions. For instance, the mutual adaptation strategy refers to the ability to create a between-unit coupling strength as a sign of a strong interpersonal action-perception coupling that leads to a "we mode" and a self and other integration. Compared to that, the model identifies two other types of interpersonal coupling that specify other modalities of staying in synchrony but from a reduced between-coupling perspective. The leader-follower and the leading-leading strategies are complementary strategies that identify a specific connection between two agents, lacking reaching a mutual adaptation since the two interactive partners decouple time by time during the interaction, hampering interpersonal coordination and, in turn, interpersonal synchrony drifts.

The action-perception loop and the mu rhythm

Different experimental approaches have been implemented to study the neural mechanisms that underpin interpersonal dynamics. According to the "isolated approach," the social cognition processes that enable people to interact with others can be understood by studying individual minds adopting a representational perspective. In line with this vein, Frith and colleagues (Frith, 2007) defined the key areas that comprise the "social brain" (Adolphs, 1999; Frith, 2007): the amygdala, orbital frontal cortex (OFC), temporal cortex, medial prefrontal cortex (MPFC), adjacent paracingulate cortex, and the mirror neuron system (MNS) (Gallese & Goldman, 1998; Rizzolatti & Craighero, 2004). However, this approach cannot explain the mechanisms that underpin social and mutual interaction within bidirectional interaction (De Jaegher et al., 2016; Konvalinka & Roepstorff, 2012; Schilbach, 2010). This limitation requires experimental set-ups involving person–person interactions and analysis methods that quantify inter-brain interactions (Konvalinka & Roepstorff, 2012).

The neural mechanisms implicated during mutual interaction refer to the activation of the action-perception loop (Hari & Kujala, 2009). During a dyadic mutual interaction, agents need to control their actions through continuous bidirectional adjusting and self-adjustments but also expect other's intentions and use them to predict and adjust what they are doing to what others are doing (Liebermann-Jordanidis et al., 2021; Pacherie, 2013). For instance, during tapping the repetition of the same action (tap) is constantly associated with the stimulus in two ways: action and perception. In other words, the simulation of external events is accompanied by the perceptive features and the relative action. However, this might be modulated by how individuals anticipate the other's actions and *perceive* the other. Notably, this activity is associated with feeling on the same wavelength and the ability to create interpersonal synchrony in a good balance between inter and intra-personal processes (Astolfi et al., 2011; Dumas, 2011; Funane et al., 2011; Lee et al., 2015; Tognoli et al., 2007). Moreover, such mechanisms require the ability to mentalize and to take the perspective of the other in terms of intentions, so they are supposed to be modulated by individual differences.

However, a group of studies on healthy samples showed that during joint attention tasks and social coordination (Dumas et al., 2011; Lachat et al., 2012; Tognoli et al., 2007), an amplitude modulation of oscillations around 10Hz (alpha band 8-12 Hz) was found over centro-parietal electrodes. This activity refers to the rolandic mu rhythm (Gastaut, 1952) that is expected to be activated during action execution and observation (Muthukumaraswamy, 2010; Pfurtscheller & Lopes da Silva, 1999; Pineda, 2005; Kuhlman, 1978). Furthermore, an open question is whether such neural activity could be a neurophysiological correlate of the mirror neurons. Consistent with that, Fox and colleagues conducted a meta-analysis on k = 85 EEG studies that revealed that the effect sizes between mu activity and MNS were significant for observation (d = 0.31) and execution (d = 0.46) occurring across different experimental conditions and actions (Fox et al., 2016). However, several concerns and inconsistencies exist concerning the association between mu activity and MNS. For instance, the overlap with the alpha band, the type of analysis, the effect size of mu suppression, or the baseline generated inconsistent results. However, understanding in which experimental and individual conditions mu rhythm could be altered is still an open research question.

The many routes to BPD

From a diagnostic point of view, Borderline Personality Disorder (BPD) relates to severe and persistent problems in emotional regulation and interpersonal relationships and is included in the cluster-B disorders involving antisocial, narcissistic, and histrionic disorders (*DSM-5*; American Psychiatric Association [APA], 2013). BPD features lead to a high variability of co-occurring moods, anxiety and eating disorders, and substance or alcohol abuse. Moreover, core problems associated with impulse control and self-regulation tend to create other difficulties, such as angry outbursts, impulsive and self-mutilating behavior, fear of loneliness, identity disturbance, and a profound sense of emptiness (Gunderson, 2009; Lieb et al., 2004; Mosquera et al., 2014; Skodol et al., 2002). Epidemiologically, BPD affects about 1.4%-5.9% of the general population (Torgersen et al., 2001). The prevalence among clinical populations ranges from 20% in psychiatric outpatient samples (Korzekwa et al., 2008) to 40% among high users of inpatient services (Comtois & Carmel, 2016). The risk for suicide is approximately 50 times that of the general population (Skodol et al., 2002; Wedig et al., 2012). In the Diagnostic and Statistical Manual of Mental Disorders-5, section III, personality disorders have been considered in relation to self-identity and interpersonal functioning features. Within this framework, personality traits are defined as “constant patterns of perceiving, relating to, and thinking about the environment and oneself, which manifest in a wide spectrum of social and personal contexts" (*DSM-5*; American Psychiatric Association [APA], 2013, p.896). BPD's domains and relative facets are Negative Affectivity, Antagonism, and Detachment. However, BPD originates in psychoanalytic thinking about patients who do not fit into the category of psychotic or neurotic but have characteristics of both (Stern, 1938). The etiology is complex and remains uncertain. Many factors contribute to the development of the disorder: genetics and constitutional vulnerabilities; neurophysiological and neurobiological dysfunctions of emotional regulation and stress; psychosocial histories of childhood maltreatment and abuse; and disorganization of aspects of the affiliative behavioral system: the attachment system.

From a psychodynamic perspective, childhood attachment is linked with the development of adult personality disorders (i.e., Meyer et al., 2001), and insecure attachment is a relevant risk factor for the development of psychopathology (Buchheim & Diamond, 2018; Clarkin et al., 2001). BPD is characterized by affect dysregulation, behavioral dyscontrol, and interpersonal hypersensitivity rooted in insecure attachment relationships and traumatic childhood experiences (Agrawal et al., 2004; Gunderson, 2007). Concerning adulthood, studies showed that using narrative methods (George, Kaplan, & Main, 1985; George & West, 2012) a strong association between BPD and unresolved attachment emerged (Bakermans-Kranenburg & van IJzendoorn, 2009; Buchheim & Diamond, 2018; Levy et al., 2006; Patrick et al., 1994). Using self-report, a strong association between BPD and fearful or preoccupied and angry/hostile attachment was found (Frias et al., 2016; Levy et al., 2011). Notably, insecure and disorganized attachment patterns were associated with maladaptive personality traits underlying BPD (Scott et al., 2009).

Consistent with a theoretical view, the lack of resolution of trauma or unresolved status on the Adult Attachment Interview (George, Kaplan, & Main, 1985) distinguishes BPD individuals from other clinical groups (Fonagy, 1996, 1998). Specifically, the reduced "capacity to understand ourselves and others in terms of intentional mental states, such as feelings, desires, wishes, goals, and attitudes" (Fonagy, 1991) is considered the mechanism that within a disorganized and traumatic attachment relationship affects the development of BPD. The traumatic experience of "frightened-frightening" (Main & Hesse, 1990) parental behavior within the interplay of self–other dyads as victim/victimizer would, in turn, lead to the development of a dissociative *alien self* and a deficiency in self-perception and emotional control (Allen et al., 2010; Schore, 2015). In this sense, mentalization was considered the mediating variable that ameliorated or exacerbated the impact of an abusive environment. Notably, Slade (2005) considered mentalization as the "core capacity" differentiating secure from insecure states of mind (Slade, 2005). Considering the importance of mentalization for self-regulation as embedded in a secure attachment interaction, mentalization has been considered a key mechanism for a change in psychodynamic psychotherapy with patients with severe personality disorder (Bateman & Fonagy, 2004; Fonagy & Target, 2002; Levy, 2005).

In parallel, Kernberg (1967,1976,1984) developed the object relation theory (ORT) as an integration of contributions by Klein, Jacobson, Mahler, and Erickson, but also provides a structural assessment in addition to the descriptive approach taken by the DSM-IV-TR (American Psychiatric Association 2000). The ORT combines the dimensional classification of personality disorder according to the severity of structural pathology with a second-order categorial classification based on descriptive traits (Clarkin et al., 2007). This approach is the first to characterize the severity of personality pathology while assessing the nature, organization, and degree of integration of psychological structures and characterize descriptive features of personality pathology to make a diagnosis of personality "type" or "style" (Clarkin et al., 2007). The components of personality functioning are the descriptive features of an individual's personality and personality pathology. The individual's personality is expressed as a particular personality style, and these descriptors are seen as "personality traits" (Clarkin et al., 2007). The ORT focuses on six core psychological structures as the organizers of self and interpersonal functioning: identity, defenses, object relations, moral values, aggression, and reality testing. Each of those structures organizes descriptive aspects of personality functioning. For instance, 'identity' refers to the sense of self and other, while 'object relations' refers to the activation of the working models that organize the interpersonal functioning (Caligor et al., 2023). Notably, Kernberg (1984) divided personality pathology into two major groups of disorders or levels of personality organization, the neurotic level of personality organization (NPO) and the borderline level of personality organization (BPO), based on the severity of structural pathology. Each level is characterized in relation to the nature of the identity formation, defenses and reality testing, the quality of the object relations, the nature of moral functioning, and aggression. Moreover, personality pathology exists on a spectrum, so when traits become more rigid or extreme, the highest level of pathology indicates a personality disorder diagnosis (Kernberg, 1984).

Borderline personality organization (BPO) stands at an intermediary level of internal personality organization between more severe psychotic personality organization and less severe neurotic organization (Clarkin et al., 2007; Kernberg & Caligor, 2005; Caligor, 2010). The BPO construct involves all serious forms of personality disorder and is characterized by three intrapsychic characteristics: 1) identity diffusion; 2) primitive defenses (e.g., splitting (devaluation-idealization), denial, projection, action, and projective identification); and 3) reality testing that was generally intact, but vulnerable to alterations and failures (Caligor, 2010). Furthermore, OBT distinguished between high-level and low-level borderline organizations. The essential distinction between the high- and low-level borderline groups is based on the quality of the object relations, moral values, and aggression. Low-level borderline organizations include paranoid, schizoid, schizotypal, BPD, and antisocial personality disorders, characterized by identity diffusion with more aggression and diminishing degrees of internal moral guidance compared to those in the high-level borderline group (Clarkin et al., 2007; Caligor, 2010).

Furthermore, Kernberg (1984) contrasts normal identity with pathological identity formation, referring to the latter as the "syndrome of identity diffusion." In this theoretical framework, the normal development of the identity coincides with the result of the four stages of separation-individuation processes (Mahler, 1963). According to that, during the symbiotic phase, the experience is organized in a paranoid-schizoid manner, and the conflicts are pre-oedipal. In the separation-individuation phase, during the internalization phase of realistic representations of the self and the other in conditions of low emotional activation, there is a gradual differentiation of the representations of the self and the object characterized by extreme affects. These representations, combined with the dominant primitive affect constitute 'partial internal units' divided into good and bad (separation-identification). The split representations begin to be integrated and form realistic representations of the self in relation to objects in which both positive and negative aspects coexist, and the affects connected to these split units begin to modulate each other (depressive anxieties). In the last phase, good and bad representations of self and others continue to unify into integrated concepts of self and others with realistic views of the self as potentially driven by impulses. The integration of split object representations translates into the modulation of affects and the structures of the psychic apparatus are consolidated. In 'identity diffusion,' internal object relations are polarized in a split view of "all good" or "all bad" and associated with strongly positive, strongly negative, and extreme affect states (Kernberg & Caligor, 2005). This contradictory internal state externalizes in unstable relationships, emotional dysregulation, and cognitive distortions. At a descriptive level, the outcome of this structural organization is the absence of an overarching, coherent sense of self or significant others. Those features have strong negative implications at the interpersonal level in everyday life and during therapy (Yeomans et al., 2015). However, studies showed that Transference Focused Psychotherapy (TFP), compared to dialectical behavioral therapy and psychodynamic supportive therapy, enhanced the patient's capacity to internalize a secure base, attachment-related autonomy, and capacity for flexible integration (Buchheim et al., 2017; Levy et al., 2006).

Consistent with the psychodynamic perspectives of object relation theory (Kernberg,1984), the structure of mental representation in terms of integrity and coherence and the representation's content influence the expectation, feelings, and behavioral patterns. For instance, insecure representational states concerning attachment are associated with a lower level of object relations, less integrated, malevolent, less differentiated, and benevolent. Pioneers studies by Lyons-Ruth and colleagues found that the mother's inconsistency and unwillingness to respond to the child's distress signals represent key elements of disorganized attachment and the best predictor for BPD in adulthood (Lyons-Ruth et al., 1999). The approach-avoidance behaviors within interactive dysregulations between mother and child represent “hidden traumas” (Lyons-Ruth et al., 2006). The *object* from which the child should receive protection, affection, and containment coincides with the threatening, wicked, and traumatic figure (Lyons-Ruth et al., 2006; Lyons-Ruth & Spielman, 2004). The infant’s internalization of contradictory models of the self as frightened or threatening and of the parent as hostile or helpless/withdrawing can be conceptualized in terms of contradictory models that generate incompatible behavioral and mental tendencies (Lyons-Ruth et al., 2006; Lyons-Ruth & Spielman, 2004). Along these lines, the child did not have the opportunity to know his/her own experiences since “they were not seen, recognized, and mirrored by the caregiver” (Beebe et al., 2015, p. 108). In turn, this might be the basis for the formation of emotional dysregulation (Linehan, 1993) and then dissociative symptoms (Lyons-Ruth et al., 2006; Sroufe, 2005). When the ‘paradox’ of the mother as ‘frightened-frightening’ is reactivated in the next relationships, it coincides with the return to a “teleological evolutionary mode” (Allen et al., 2010), pretend mode or psychic equivalence generating an imbalance in mental and affective states leading to serious instability. Such modality of pre-mentalizing typical of BPD leads to projective identification, defined as “the tendency to create an unacceptable experience inside the other” (Klein, 1946; Kernberg, 1976). Along these lines, children's internal working models with insecure-resistant and disorganized attachment were compared (Beebe et al., 2012; Lyons-Ruth et al., 1999). Both shared the instability at interpersonal and emotional levels. However, the author observed that while the insecure-resistant attempted to get close to the mother, trying to understand what she had in mind and to be involved during the interaction, the disorganized was chaotic and created expectancies of not being “seen,” increasing the distress and the negative affect. In this sense, the incongruence expectations about the affect and the behavioral physical proximity will increase the negative representation of the self and of self in relation to the other, sustaining persistent incoherent and disorganized behaviors and dysfunctional ways of perceiving the external stimulus. Such disturbances within the evolutionary framework of attachment might remain through the lifespan and emerge in the *rigidity* of the personality structures developed within a 'disorganized' and traumatic interactive exchange where the emotional dysregulation and the constant unpredictability and uncertainty hampered the possibility of knowing self and others in terms of intentions, mental and affective states (Euler et al., 2021; Fonagy et al., 2017).

Some evidence in social cognition and BPD

BPD has been considered a "disorder of dysregulation" (Linehan, 1993) rooted in early interaction through the constant transactions between biological vulnerabilities and an invalidating attachment environment. In line with this view, Paris (1996) proposed a multidimensional model, the 'biopsychosocial model,' defining that the amplification of personality traits is a consequence of the impact of various risk factors. The interplay of biological (neuropsychological dysfunctions and the hereditary aspect of temperament), psychological (traumatic expression), and social factors design etiological routes. In this sense, biological vulnerability in the development of personality pathology represents an essential element of the diathesis-stress theory: diathesis are the risk factors, innate factors, and individual differences that influence vulnerability to mental disorders. Diathesis is the type of pathological trait that the patient will develop while the stress activates this potential. However, within this perspective, childhood abuse is the main traumatic experience, which, in turn, produces cascade effects. Specifically, "family functioning" represents one of the main social structures that can be expected to influence the risk of pathology. In this sense, the lack of secure attachments is a social risk factor for emotional dysregulation. Based on such a theoretical perspective, the higher emotional reactivity of BPD develops within unstable and vulnerable attachment relationships that lead to difficulties in social cognition, recognizing emotions, and establishing relationships (Allen et al., 2010; Schore, 2015). Neurobiological alteration and neuropsychological-specific profiles drive the evaluation of the social stimulus and the behavioral response resulting from a reduced cortical inhibition of the emotional reactivity (Herpertz et al., 2018; Herpertz & Bertsch, 2014). According to Kernberg (1984/1976), 'affects' are the building blocks of motivation and the signals that activate and deactivate them, while internalized object relations made up of representations of the self in relation to the other and charged with affect are the bricks with which psychic structures are built. Considering that emotional activation and emotional dysregulation are at the center of the diagnosis of BPD patients, trauma chronically activates the neurobiological systems underlying negative emotional responses that facilitate the subsequent expression of such responses and intensifies the aggressive tendencies that develop starting from internalized object relations characterized charged with highly negative affects (Clarkin et al., 2007; Kernberg & Caligor, 2005).

Along with these theoretical frameworks, empirical findings (Herpertz & Bertsch, 2014; Poggi et al., 2019; Roepke et al., 2013) show that individuals with BPD or BPD features are associated with a higher sensitivity to social stimuli that seem to sustain problematic interpersonal social functioning and the higher extreme negative affect. For instance, individuals with BPD show a reduced ability to trust others interacting with low cooperation and generous behaviors (i.e, King-Casas et al., 2008; Seres et al., 2009) but also to appraise trustworthy or neutral faces as untrustworthy or negative (Fertuck et al., 2013, 2019; Richetin et al., 2018). According to Allen (2013) "trust may be undermined or destroyed by social adversity, especially attachment trauma" (Allen, 2013). Consistent with that, the adversities in disorganized attachment relationship - as a possible precursor of BPD (Fonagy & Luyten, 2009; Gunderson & Lyons-Ruth, 2008)- could hamper the development of epistemic trust that is "one's ability to trust others and rely on the information they convey as being relevant and generalizable" (Fonagy et al., 2015). This might develop in relation to a reduced experience of "marked mirroring interactions" and ostensive cue (Fonagy & Target, 2002; Gergely

& Watson, 1996) hampering self-knowledge but also the social learning, the "we mode" and sharing in therapy (Fisher et al., 2023; Milesi et al., 2023). In turn, these features generate a failure in communication and important negative consequences in creating relationships and during therapy where "BPD patients are difficult to reach" (Bateman & Fonagy, 2004; Kernberg & Caligor, 2005).

Furthermore, the relationships between BPD features and mistrust or the untrustworthiness bias (Fertuck et al., 2013) seems to be mediated by the higher rejection sensitivity (Miano et al., 2012) that entails a cognitive and affective negative disposition "*to anxiously expect, readily perceive, and strongly react to the mere possibility of rejection in interpersonal situations"* (Downey & Feldman, 1996). This is a central feature that enhances the mistrust rooted in the attachment relationship where the individual develops higher expectations of being rejected and fear of abandonment (Gunderson & Lyons-Ruth, 2008) about being rejected. In other words, the distorted representation of others as malevolent and rejecting and of self as rejected or abandoned might be the main foundational features of a deficit in trusting others and cooperating with them.

Such dynamic, along with higher harmful and emotional components (i.e, Berenson et al., 2011) generates strong difficulties in interpersonal relationships. For instance, Lazarus and colleagues found that rejection sensitivity mediated the relationship between BPD and the relationships with romantic and non-romantic partners (Lazarus et al., 2018). According to the authors, "this pattern may drive individuals with BPD not to reinforce accepting behaviors in their partners, who in turn may reduce these behaviors, thus leading to a vicious cycle" (Lazarus et al., 2018). Moreover, individuals with BPD features and BPD patients reported a lower effortful control, lower tolerance of ambiguity, and higher rejection sensitivity that might result in higher negative affect as well as impulsive and destructive reactions (Downey & Feldman, 1996). Along this line, studies showed that effortful control mediated and moderated the association between rejection sensitivity and BPD features (De Panfilis et al., 2016; Sato et al., 2018). These findings denote that BPD shows reduced cognitive control, resulting in dysregulation at interpersonal levels. When the hypervigilance of the situation is not well-balanced by the top-down processes, the distorted interpretation of the external stimulus and the negative affect hamper the possibility of reaching a well-modulation of emotions and behaviors (impulsivity). Moreover, individuals with BPD show impairment in the reappraisal of the negative emotions (Koenigsberg et al., 2009). In other words, those individuals cannot reduce the affective negative response to the stimulus through a re-elaboration of the stimulus and modulating the response. When the stimulus elicits negative emotions, the bottom-up impairments (at the ventromedial prefrontal activity) reduce cognitive control. In contrast, the amygdala's activity increased, leading to no modulation of the negative affect and reduced attentive patterns (Rothbart & Posner, 2015).

Furthermore, one main feature differentiating BPD patients from patients with other personality disorders (Arntz et al., 2004) is the high rejection and abandonment-related beliefs (Butler et al., 2002; Chapman et al., 2014). In turn, such higher sensitivity toward rejection (Berenson et al., 2011; Staebler et al., 2011) is associated with high negative affect precisely hostility (Romero-Canyas et al., 2010) and aggressive behaviors (Herr et al., 2013; Scott et al., 2017). Along these lines, BPD patients reported increased negative affect (Dixon-Gordon et al., 2011, 2017) and hostility (Chapman et al., 2014; Renneberg et al., 2012) following experimentally induced rejection. However, also momentary rejection predicted increases in aversive tension (Stiglmayr et al., 2005), affective instability, and intense anger (Miskewicz et al., 2015). Notably, the main characteristic of the negative affect of BPD is the high instability and fluctuations that cause rapid changes in mood (Carpenter & Trull, 2013; Crowell et al., 2009). In this sense, those individuals interpret interpersonal stimuli as a potential predictor of negative affects (e.g., anger, fear, sadness) (Daros et al., 2014; Domes et al., 2008; Lazarus et al., 2014). Moreover, emotion recognition seems to be sensitive to the characteristics of the context in which the face is presented: in complex and more structured tasks, individuals with BPD show more impairments than the controls (Dyck et al., 2009; Minzenberg et al., 2006).

Additionally, individuals with BPD reported a reduced sensation of social connection when "over-included" (De Panfilis et al., 2015) or in the presence of acceptance signals (Liebke et al., 2018). This extremely negative evaluation of actions and attributions to others' intentions is a central and distinctive feature of BPD patients vs non-BPD or control (Arntz & Veen, 2001; Barnow, Völker, et al., 2009). Moreover, a series of studies (Dziobek et al., 2011; Flasbeck & Brüne, 2019; Guttman & Laporte, 2000; Harari et al., 2010; Petersen et al., 2016) revealed that BPD patients showed impaired perspective taking compared to the control group.

Furthermore, other body of studies investigated the mental attribution in BPD, revealing that BPD patients showed no deficit in mental state attributions compared to the controls (Dziobek et al., 2011; Schilling et al., 2012) but rather an enhanced accuracy in inferring emotional states (Fertuck et al., 2006). These divergent findings were supposed to be related to the characteristics of the proposed task. Moreover, Sharp (2014) developed a "hyper mentalization model" to combine mentalizing and social-information processing theory where mentalizing is increased as a result of an over-attribution of mental states that are "far beyond what there is evidence for" (Sharp, 2014). This mechanism seems related to the tendency to project their minds into other minds (Sharp, Fonagy & Goodyer, 2008). A recent systematic review and metanalysis (McLaren et al., 2022) on N = 36 studies using the Movie for the Assessment of Social Cognition MASC (Dziobek et al., 2006) revealed that there is an association between psychopathology and hypermentalizing (r = 0.24). Still, it was not strongly related to borderline personality disorder (r = 0.26) than to other disorders (r = 0.24). However, considering the mixed results, more research is encouraged.

Taken together, the core mechanisms of emotional dysregulation reflecting high negative affect and distorted interpretations of social stimuli sustain the interpersonal difficulties concerning BPD features. Moreover, little is known about how such social-cognitive components might interfere with the processes implicated during interpersonal coordination in the construction of a co-representation of self and other actions that, in turn, might hamper interpersonal synchrony.

A brief focus on self and other within a neural perspective

According to the OBT (Kernberg, 1967), psychological structures are stable and long-lasting patterns of psychic functions that organize behavior, subjective experience, and perception. The 'object relations' are the building blocks of the psychological structures and act as organizers of motivation and behavior. The representation of the self and the other are representations of how they were experienced and internalized during early relations and the result of the elaboration of internal forces (primary affects) (Yeomans et al., 2015). Individuals with BPO might present an unstable sense of self as a result of the unmetabolized introjects, which are "experiences of the self-concerning the caregiver characterized by contradictory aspects of the self and the others that are poorly integrated and separated" (Kerberg & Caligor, 2005). Such split and polarized views of self and others might play a central role in engaging in attuned interaction where cognitive and affective processes are implicated.

Recently, De Meulemeester and colleagues analyzed the role of self and other distinctions in social interaction at behavioral and neural levels in BPD (De Meulemeester et al., 2021), proposing a model to understand better the nature of the difficulties in differentiation between self and other in BPD. According to this perspective, an impaired ability for flexible self-other switching in BPD may result in either egocentric (rigid focus on self) or altercentric bias (rigid focus on other). The egocentric bias is associated with a reduced perspective-taking ability resulting in attributing to others their own mental states instead of considering the others as separate from their own with a personal perspective. Furthermore, the altercentric bias occurs when the focus is on others' mental states, so individuals with BPD might exhibit a high automatic resonance that causes them to experience the others' emotions, perceiving them as their own. In relation to the interpersonal context, attachment hyperactivation associated with anxious attachment might be associated with altercentric bias in BPD. However, the typical approach-avoidance dilemma (Main & Hesse, 1990) observed in BPD during interaction may result in embodied self and other distinction (SOD) impairment. Specifically, the conflicting attachment strategies could result in a desire for self-other merging vs. self-other distance, leading to relational imbalance and a problematic co-representation of self and other.

According to some studies, the ability to share mental and emotional states relies on neural processes such as the shared representational system (Ripoll et al., 2013) and the mental state attribution system (MSA) (Fonagy & Target, 1998). In this context, fMRI studies showed that BPD patients had a greater activity of the somatosensory and premotor cortex and the amygdala than the control (Dziobek et al., 2011; Haas & Miller, 2015; Mier et al., 2013). This hyperactivation of SR corresponded with a hypoactivity of the MSA. Another group of studies (Beeney, 2014; Bo et al., 2017; Bozzatello et al., 2019; Sharp & Vanwoerden, 2015), showed a hypoactivation of somatosensory areas reflected in hyperactivation of MSA along with a hypoactivation of the SR leading to hypermentalizing engaging in excessive and overly cognitive effort. Fonagy and Luyten defined that the typical imbalance between these two mechanisms and the front-limbic dysfunctions in BPD might be impacted by the emotional arousal and interpersonal stressors that activate the attachment system (Fonagy & Luyten, 2009). Attachment-related stress has been found to lead to a deactivation of MSA areas important for SOD, such as the left temporo-parietal junction and the left superior temporal sulcus (STS) (Nolte et al., 2013). These findings shed light on the cognitive and neural consequences of an insecure-disorganized attachment (Agrawal et al., 2004; Gunderson & Lyons-Ruth, 2008): the parental reactions to infant distress could have been inconsistent, interfering with the growing intersubjectivity, attuned relationships, and the neural formations of shared representations and mental attributions (De Meulemeester et al., 2021). Although functional studies have already investigated the profile of BPD patients and a limited number of EEG studies have already explored the temporal activity taken an “individual” approach (Ruocco & Carcone, 2016), little is known about the temporal EEG activity of individuals with BPD features during social interaction. In this sense, an imbalance between extreme poles such as cognition-emotion, implicit-explicit, internal-external, and self-other (Fonagy & Luyten, 2009) might hamper the ability to perceive and integrate the self and other's actions representations, resulting in altered EEG rhythm.

Moving on toward the change: nonverbal synchrony in psychotherapy

Psychotherapy is a dynamic setting in which therapist and patient share the same interactive space, and the bodies and minds harmonize and coordinate together in an ongoing interactive process of mutual adaptation, thereby reciprocally influencing (Butner et al., 2014; Dahl et al., 2016; Flückiger et al., 2018; Gelo & Salvatore, 2016). Within this interactive setting, the quality of the therapeutic relationship is an essential feature for enabling *therapy to be* (Ackerman & Hilsenroth, 2001; A. Horvath & Luborsky, 1993; Mikulincer & Shaver, 2007; Smith et al., 2010).

Freud (1912) introduced the concept of the therapeutic alliance while discussing various types of transferences, arguing that conscious and positive transference constitutes a welcome and useful component of the therapeutic bond. Bowlby (1988) identified the centrality of creating and sustaining intimate emotional bonds with others as a primary characteristic of effective personality functioning and mental health (Bowlby, 1988). Within therapy, the 'therapist' is supposed to provide protection and an authentic experience of "being with." However, many factors are implicated during such a process, where the patient's approach to the interaction and the ability to build a relationship reflects the patient's attachment patterns and mental representation of self and others (Meyer & Pilkonis, 2002; Mikulincer & Shaver, 2007). For instance, patients with a secure attachment are more involved with self-exploration, self-disclosure, collaborative understanding with the therapist, and being able to reflect on and appraise their past and current relationships. This helps to form a good quality alliance and maintain it by repairing ruptures that develop.

Conversely, patients with an insecure attachment pattern tend to avoid interpersonal closeness with the therapist, have a continuous vacillation between devaluation and idealization, expect rejection, and do not trust the therapist. This could impede or delay the formation of a good alliance. In this sense, the therapeutic change occurs as insecure clients, contrary to their previous experience, live a secure and responsive relationship with their therapist (Bowlby, 1988). Consistent with that, studies showed that throughout psychotherapy, a decrease in symptoms was associated with an increase in self-reported secure attachment (Travis et al., 2001). If this experience deviates from the individuals' early prototype models, their core attachment pattern may be modified (Daniel, 2006). Results converged on the idea that there is a positive significant relationship between attachment security and a strong therapeutic alliance, while attachment insecurity was associated with a weaker therapeutic alliance (Diener & Monroe, 2011; Smith et al., 2010).

Keeping a psychodynamic perspective, during the formation of the therapeutic bond, the patient could experience a secure relationship, get out of a *psychic equivalent* (Fonagy & Target, 1998), and get in touch with one's intersubjective world while the therapist and the patient work together in a "we-mode" as a form of "being recognized" by the therapist nourishing epistemic trust (Fisher et al., 2023; Fonagy et al., 2015, 2017). In this way, the therapy would develop through a trait-like and state-like mutual *dance* relying upon the three main dimensions introduced by Bordin (1979) to conceptualize the alliance as a "working alliance": (1) agreement of goals; (2) assignment of tasks; and (3) the development of bonds, that is the development of enough trust, respect, confidence and personal attachment between the therapist and the client to achieve the goals and take part in the task (Bordin, 1979). However, more research is needed to understand which mechanisms could sustain and facilitate the establishment of the alliance. For instance, patients with severe personality disorders show severe impairments in building the alliance due to the high interpersonal vulnerabilities and rigidity that hamper the therapy from the early stages. The big step in this vein sometimes is just to "let the therapy begin" (TFP) (Yeomans et al., 2015).

Along these lines, much interest has recently been addressed in the study of interpersonal coordination and different forms of synchrony (Atzil-Slonim et al., 2023; Wiltshire et al., 2020) that might play a relevant role in *maintaining* the patient in the therapy. The behavioral study of nonverbal synchrony emerged based on William Condon's *approach* (Condon & Sander, 1974), who analyzed (microanalytically) frame-by-frame videos of social interactions, revealing that changes in movements and phonetics had a cooccurrence. Moreover, this suggests that motion changes within a person do not occur randomly but instead cluster as simultaneous events called “process units” and mutually influence each other. Along this vein, Ramseyer and Tschacher were the first to demonstrate that nonverbal synchrony measured using a computational approach during therapeutic sessions was associated with alliance and therapy outcomes (F. Ramseyer & Tschacher, 2010, 2014). Specifically, The Motion Energy Analysis (MEA) has been implemented to measure nonverbal synchrony at the behavioral level (F. T. Ramseyer, 2020). MEA is based on the assessment of differences in sequences of video frames in recordings of therapeutic sessions. To quantify synchrony, different algorithms are used for the calculation of synchrony based on the correlations of the individual time series to give a measure of the overall synchrony during therapy. Given the well-investigated relational nature of synchrony, psychotherapy researchers are approaching to analyze the role of synchrony in association with the alliance and the therapy outcome (i.e., Wiltshire et al., 2020).

Koole and Tschacher proposed the Interpersonal Synchrony (In-Sync) model as a new theoretical framework to analyze the alliance's role in association synchrony and the effect on emotion regulation (Koole & Tschacher, 2016). Moreover, the model provided the view of the alliance as a collaborative dimension that emerges within the coupling of cognitive and affective processes between the patient and the therapist. However, the mutual coordination of synchronous activities and sharing experiences allows the patient and the therapist to communicate. In this sense, the model distinguishes three levels of processing and the different time at which each level operates: the perceptual-motor processes (level 1 – phasic timescale), complex cognition (level 2 - tonic timescale), emotion regulation (level 3 - chronic timescale). The movement synchrony (level 1) coincides with the perceptual-motor system that can be expressed through different modalities. According to the well-explored positive role of synchrony at the affective level (Hove & Risen, 2009; Vacharkulksemsuk & Fredrickson, 2012; Valdesolo et al., 2010), the authors suppose that movement synchrony would facilitate the action-perception loop and the social-cognitive processes (level 2) and increase alliance. At this stage, the mental representation grows during the movement and the formation of common goals and intentions. In this sense, synchrony might be a basic component of the perceptual-motor processes while the alliance emerges. Notably, the model analyzes the three interacting components of the alliance that enhance how movement synchrony is a well-extensive phenomenon that covers different relational features (vocal, movement, and physiology). First, adopting a common language through mutual adaptation to another's linguistic behaviors (linguistic alignment) might sustain the shared mental representations and the "task- and goal-related aspects of the alliance" (Bordin, 1979). Then, the mutual sharing of subjective experiences (I-sharing) promotes social bonding, affective co-regulation, and responses. At this stage, synchrony could be expressed through complementary ways of responding to the patient, and they both return to their homeostatic balance. Starting from this improvement in the patient's self-regulatory capacities, the model distinguishes between explicit and implicit emotion regulation. The explicit level is based on self-insight and conscious emotion-regulatory strategies and techniques mediated by the common language. Implicit emotion regulation is more automatic and derives from the combination of the three components of the alliance, which allows the patient to internalize the beneficial effect of the co-regulation (Gyurak et al., 201; Koole & Rothermund, 2011).

In conclusion, the In-Sync model is a promising framework for ascertaining the processes that might sustain the alliance during therapy, enhancing the importance of the interplay between the behavioral and cognitive-affective dimensions in the co-construction of the therapeutic bond. Furthermore, to the best of our knowledge, this is the first model that considers synchrony within a theoretical framework combining the interpersonal dimension of synchrony with trust, mutual collaboration, and cooperation. Based on this model, recent findings (Atzil-Slonim et al., 2023; Wiltshire et al., 2020) suggested that "being with" during therapy at the nonverbal level could affect the therapeutic process and benefit interpersonal functioning (i.e., K. Cohen et al., 2021; F. Ramseyer

& Tschacher, 2011). However, more research is needed to investigate whether synchrony and its several forms could play a role during therapy. In this sense, going back to a psychodynamic perspective, the therapy would be not only a new experience for "new significances" but also a *present* moment for the patient to learn how to communicate a more adaptive sense, "staying with" and "feeling close."

Overview of the chapters

The architecture of the chapters follows this structure. In section one, we will present an experimental approach investigating the role of high BPD traits in association with the mechanisms underpinning interpersonal coordination that sustain interpersonal synchrony at behavioral, neural, and affective levels. In all the studies included in the section, we operationalized interpersonal synchrony using a finger-tapping task, and to manipulate the temporal adaptivity of the interactive partner, we used a computational model (Fairhurst et al., 2013; Van Der Steen & Keller, 2013). Chapter 1 explores whether BPD traits could modulate interpersonal synchrony at behavioral and emotional levels when interacting with a variable adaptive partner. Chapter 2 presents an EEG study investigating at the neural level whether BPD traits could modulate mu rhythm during self and other synchronized interactions. Chapter 3 investigates, across three studies, the bidirectional relationship between trustworthiness and synchrony and the role of BPD traits in these associations. Specifically, in studies 1 and 2, we investigate whether trustworthiness affects synchrony, while in study 3, we explore whether synchrony impacts trustworthiness.

In section two, Chapter 4 attempts to investigate the strength of the association between nonverbal synchrony and alliance and nonverbal synchrony and therapeutic outcomes. Toward a more comprehensive view, the moderation effect of the therapeutic approach in both relationships was tested. Although this study is at the end of the thesis, this will be the *glue* between our findings that will trace the new potential routes for clinical interventions.

Section One

Which mechanisms underpin interpersonal coordination?

THE ROLE OF HIGH BPD TRAITS

CHAPTER 1

Stable asynchrony? Association between borderline personality traits and interpersonal asynchrony *(under review)*

Gregorini, C., De Carli, P., Parolin, L., Petilli, M., Konvalinka, I., & Preti, E.

ABSTRACT

Interpersonal synchrony is a relational phenomenon linked to prosocial behavior and affiliation. It requires interpersonal coordination and well-defined interactive flexibility to emerge. While research has investigated the general underlying mechanisms that facilitate interpersonal synchrony, much less is known about the role of psychopathological conditions – such as Borderline Personality Disorder (BPD)- in modulating these processes. In this study, we investigated the association between BPD traits and interpersonal synchrony. Participants (N = 206) were recruited from the general population. BPD traits were assessed, and interpersonal synchronization ability was measured with a finger-tapping task. Participants were instructed to interact with a virtual partner (VP) that varied its cooperation level in response to their taps across different conditions of adaptivity (α), ranging from non-adaptive to overly adaptive. After each interaction, the subjective experience of the interaction was assessed. Results showed an overall main significant effect of the adaptivity of the VP on interpersonal synchrony and on the experience of the interaction, such that as VP adaptivity increased, asynchrony decreased, while perceived synchrony also decreased. High levels of BPD traits were associated with higher asynchrony and variability, depending on the level of VP adaptivity and an overall more negative perception of synchrony and affect. These findings show that BPD traits are associated with impaired interpersonal synchrony. Future clinical directions are outlined.

Introduction

Humans have a natural ability to coordinate their movements with others with little apparent cognitive and conscious effort. Interpersonal coordination requires a continuous interplay of cognitive and social processes such as anticipation and adaptation to the other's actions as well as self and other distinction and integration. Moreover, interpersonal synchrony has been found to be both intentional or spontaneous (Dumas & Fairhurst, 2021; Richardson et al., 2007; Schmidt & O'Brien, 1997; Schmidt & Richardson, 2008). Dyads or groups of people could be intentionally synchronized when they are performing in a symphony orchestra or dancing (Nowicki et al., 2013; Reddish et al., 2013). However, when walking next to each other (van Ulzen et al., 2008; Zivotofsky & Hausdorff, 2007) or when engaging in a conversation, walking strides, postural sway and gestures become spontaneously synchronized (LaFrance, 1979; Shockley et al., 2003). While the functional significance of interpersonal synchrony is still debated, much research has pointed out that the synchrony could be related to a "social glue" during an interaction (Lakin et al., 2003). Some studies showed that synchrony seems to increase prosocial behaviors, affiliation, social cohesion, and cooperation (Bernieri et al., 1988; Chartrand & Lakin, 2013; Hove & Risen, 2009; van Baaren et al., 2009; Vicaria & Dickens, 2016; Wiltermuth & Heath, 2009). However, despite clear evidence that synchrony plays a role in relational and intersubjective processes (Feldman, 2003; Trevarthen & Aitken, 2001), its interplay with personality traits remains largely unexplored. Here, we will focus on investigating whether pathological personality traits related to borderline personality disorder might be involved in the processes that underpin interpersonal coordination during synchronized interaction.

Borderline Personality Disorder (BPD) is one of the most severe and challenging mental disorders (American Psychiatric Association [APA], 2013; Lieb et al., 2004) characterized by core symptoms such as emotional instability, impulsivity, identity disturbance, problematic interpersonal relationships, and self-harming behaviors (Gunderson, 2007; Skodol et al., 2002). Disturbances in early relationships and insecure or unresolved-disorganized attachment relationships are considered etiological factors of the BPD (Agrawal et al., 2004; Gunderson & Lyons-Ruth, 2008). Along this line, one of the main aspects that characterize BPD interpersonal functioning is the tendency to establish unstable and negative relationships (Gunderson, 2007; Lieb et al., 2004) characterized by a constant vacillation between idealization and devaluation (Kernberg, 1967). This feature invalidates the subject's social experience and occurs in romantic relationships (Downey et al., 1998; Lazarus et al., 2018; Miano et al., 2017), friendship (i.e, Runions et al., 2021) and during therapy (Caligor et al., 2018; Fonagy & Bateman, 2008; Linehan, 1993).

According to the biosocial model of Linehan (Linehan, 1993), BPD patients were theorized to show high emotional dysregulation. This is expressed through two central components: high levels of emotional sensitivity and negative affect (Carpenter & Trull, 2013; Crowell et al., 2009; Linehan, 1993). Studies showed that such emotional sensitivity is associated with high negative states (e.g., anger, fear, sadness) in reacting to environmental stimuli interpreted as negative (Daros et al., 2014; Domes et al., 2009; Lazarus et al., 2014). Specifically, individuals with BPD show a combination of emotional vulnerability and emotion dysregulation characterized by high instability and fluctuations of negative affect that cause rapid changes in mood. Specifically, individuals with BPD show less accurate emotion recognition when the environmental stimulus is neutral or ambiguous (Mitchell et al., 2014; Richman & Unoka, 2015) or is presented in a complex and structured environment (Minzenberg et al., 2006). In relation to trust appraisal, individuals with BPD traits rated trustworthy faces as less trustworthy vs. control (Fertuck et al., 2013; Miano et al., 2013), and this result was replicated by Richetin and colleagues showing that individuals with high BPD traits perceived neutral faces as more untrustworthy than individuals with low BPD traits (Richetin et al., 2018). Furthermore, several studies have investigated the relationship between BPD traits and rejection sensitivity (Ö. Ayduk et al., 2008; Boldero et al., 2009; Butler et al., 2002; Fertuck et al., 2013; Meyer et al., 2005; Rosenbach & Renneberg, 2014; Staebler et al., 2011) suggesting a positive relationship between higher rejection sensitivity and higher negative affect. Moreover, such cognitive bias could sustain a paranoid and hostile view of the world (Kernberg & Caligor, 2005), increasing negative affect. In turn, such emotional dysregulation concerns the inability to modulate emotions within the interaction and sustained impairment concerning trust, cooperation, and affiliation. Furthermore, individuals with BPD or high BPD features showed higher negative affect when involved in interpersonal situations of rejection and hostility (Beeney et al., 2014; Berenson et al., 2021; Sadikaj et al., 2010, 2013; Stiglmayr et al., 2005) showing maladaptive strategies to face the situation (Dixon-Gordon et al., 2011). Other studies showed that individuals with BPD features showed heightened negative emotions in any social scenario (Renneberg et al., 2012) or felt excluded even when objectively included (De Panfilis et al., 2015; Staebler et al., 2011) and less social connection when "overly included" (De Panfilis et al., 2015). Then, during an economic game, individuals with BPD showed lower cooperative attitudes (King-Casas et al., 2008) and more "timing deviations" during joint musical improvisation (Foubert et al., 2017). Consistent with these findings, the social cognitive deficits related to BPD and individuals with high BPD traits might drive the interpretation and the social information processing rooted in early significant interactions (Agrawal et al., 2004; Gunderson & Lyons-Ruth, 2008). Such emotional dysregulation might be sustained by negative affective states that tend to be projected to others based on a split view of self and other (Kernberg & Caligor, 2005). Along this vein, individuals with BPD might relate to others with a disrupted mentalization (Fonagy & Bateman, 2008; Sharp et al., 2009) that refers to a metacognitive capacity "to reflect on one's own thoughts and feelings and those of others" (Bateman & Fonagy, 2004) as one attempt to predict and understand the mechanisms behind behaviors.

Consistent with these findings and theoretical perspectives, individuals with high BPD features might show difficulties in social cognitive and affective processes related to the ability to temporally align their behavior to the other's action and functionally modulate their emotions in relation to the processing of the social information. Here, we used a finger-tapping task to test whether high BPD traits could modulate interpersonal coordination processes to reach interpersonal synchrony in different conditions of temporal adaptation. Specifically, this paradigm enabled us to obtain a quantitative synchrony measure of accuracy and variability. The asynchronies were considered the “delays” as the quantitative measures of the ‘difficulties’ in maintaining the rhythm and staying in synchrony (Repp & Keller, 2008). Notably, interpersonal coordination seems to be sustained by the flexible ability to plan and monitor own and others’ actions (Repp, 2005; Repp & Keller, 2008; Van Der Steen & Keller, 2013) as well as by creating a good balance between the self-other integration and segregation to reach a “we representation” (Heggli et al., 2021; Kourtis et al., 2019). Furthermore, according to recent models (Heggli, Cabral, et al., 2019; Heggli et al., 2021) and relevant findings (Heggli, Konvalinka, et al., 2019; Konvalinka et al., 2010) the mutual adaptation is a functional synchronization strategy that strengthens how well people can integrate action-perception coupling during interaction.

In addition, since we were interested in exploring how BPD traits might modulate synchrony as a function of different levels of temporal adaptivity we used a virtual partner (VP) that responded to the participant’s tap, adopting a wide and well-controlled temporal manipulation (phase correction, α) (Fairhurst et al., 2013; Repp & Keller, 2008; Vorberg & Wing, 1996) based on a computation model (Van Der Steen & Keller, 2013). Consistent with this, the coupling strength could vary according to the degree to which the VP reduced the asynchrony from non-adaptive - when the VP interacts with no adaptivity ($\alpha = 0$) - to overly adaptive - when the VP over-corrects the asynchronies ($\alpha = 1$). On the one hand, this enabled us to test the role of BPD traits in relation to the cognitive processes implicated in how individuals perceive the stimulus and modulate synchrony as a function of information processing. On the other hand, we could also explore how BPD traits modulate synchrony in different scenarios of temporal adaptation resembling different degrees of interactive contingency and responsiveness.

In line with previous studies that used a similar manipulation on the general population (Fairhurst et al., 2013, 2014; Mills et al., 2015, 2019), we hypothesized a main effect of the different levels of

VP adaptivity in modulating the tapping performance and the subjective experience. However, we supposed that the interpersonal instability and emotional dysregulation (Lieb et al., 2004) of individuals with high BPD traits might lead to more difficulties in anticipating and adapting the other actions (VP) regardless of "when" and "how" the VP adapts. This will result in overall higher asynchrony (the delay between the tap of the participant and VP), variability, and higher variability in predicting the next VP's action. Then, concerning the higher negative affect as the main component of emotional dysregulation (i.e, Arntz & Veen, 2001; Hepp et al., 2017), we expected that individuals with high BPD traits might be associated with a higher negative subjective experience resulting in a lower perception of synchrony and higher negative affect.

Moreover, since previous studies have found that the VP modulated the performance (Fairhurst et al., 2013; Mills et al., 2015), as a more exploratory hypothesis, we expected a moderation effect of BPD traits in interaction with the levels of VP adaptivity. However, individuals with high BPD traits are expected to show higher asynchrony, variability, and variability in predicting the next action and a higher negative subjective experience than individuals with low BPD traits. For instance, when the level of adaptation increases (α is different from 0) and the participants are asked to adopt a certain level of flexibility during the interaction, individuals with high BPD traits might be unable to benefit from mutually interpersonal adaptive exchanges and regulate their emotions and feel social closeness.

In addition, we focused on a specific feature of BPD that is the tendency to establish negative and unstable relationships characterized by chaotic and disorganized social approaches sustained by negative states (Bender & Skodol, 2007; Hepp et al., 2017; Levy, 2005). Notably, we expected that high levels in this specific dimension would have been associated with greater asynchrony, variability, and variability in predicting the next action regardless of VP adaptivity. Additionally, we expected that those individuals would experience the interaction with higher negative affect than individuals with low levels of negative relationships, showing more impairments in modulating affect in relation to the VP’s response. Even in this case, as a more exploratory hypothesis, we expected a moderation effect of the trait level in interaction with the variability of the VP. However, we hypothesized that even if the VP had modulated the behavioral and emotional experience (Fairhurst et al., 2013; Mills et al., 2015), individuals with high tendencies to establish unstable relationships and experience negative feelings would exhibit an overall worse performance than those with low negative relationships.

Method and Measures

Participants and procedure

Participants were recruited after a priori analysis conducted using G*Power software (latest ver. 3.1.9.7; Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany; http://www.gpower.hhu.de/) that required a minimum sample size of 191 for a two-tailed test with power 0.80, alpha 0.05, and effect size 0.2. After the approval by The Institutional Review Board of the University of Milan Bicocca, N = 206 participants (130 females, 62.9%, 75 males, 36.6%, 1 other, 0.5%; *Mage* = 24.4, *SDage* = 8.09) from the general population were recruited. Most of them (202, 98.05%) reported having no musical experience. All participants gave written informed consent to be involved in the study. Participants were seated in front of a single computer screen and were asked to fill in an online general demographic questionnaire. Then, participants were asked to complete the Personality Assessment Inventory-Borderline Scale (PAI-BOR) (Morey, 1991) via Qualtrics to evaluate BPD traits. After the personality assessment, participants were presented with a finger-tapping task (Fairhurst et al., 2013) in which they were instructed to synchronize as accurately as possible their “taps” with the “tones” produced by the computer (virtual partner, VP). The VP adaptivity (i.e., the level of the adaptation of the VP to the participants' responses) varied during the task according to a specific parameter generating different scenarios of synchronization. At the end of each block, participants were prompted to fill out subjective measures on the perception of synchrony and affect related to the previous interaction. The procedure is illustrated in Figure 1.

Personality assessment

To assess BPD features, participants completed the Personality Assessment Inventory-Borderline Scale (PAI-BOR) (Morey, 1991). PAI is a 344-item self-report measure of personality that is reliable in assessing borderline features (Stein et al., 2007). In this study, we included only the Borderline section (PAI-BOR) composed of 24 items corresponding to 4 subscales: affective instability (BOR-A, 6 items), identity problems (BOR-I, 6 items), negative relationships (BOR-N, 6 items), and self-harm (BOR-S, 6 items). Participants were asked to select the response that best pertains to them. Each item was rated on a 4-points scale ranging from "Not true at all" to "Very true". For the purposes of this study, we focused on the global scale (PAI-BOR, Cronbach's $\alpha = 0.87$) and the negative relationships subscale (BOR-N, Cronbach's $\alpha = 0.70$) (Fig.1A).

A score $\geq$38 on PAI-BOR suggests the presence of high BPD features but not necessarily a BPD diagnosis (Trull, 1995). In our study, the 88.83% of the participants were above the cutoff vs. 11.17%.

Finger tapping task

The experiment was programmed in Matlab R2020b (Mathworks Inc., Natick, MA, USA) using Psychtoolbox (version 3.0.17; Brainard, 1997; Kleiner et al., 2007; Pelli, 1997).

The procedure of the finger tapping task was developed following previous literature (Repp, 2005; Repp & Keller, 2008; Vorberg & Wing, 1996). The experimental session consisted of different conditions of human-computer interaction that varied on the level of VP adaptivity (non-adaptive, optimally adaptive, moderately adaptive, highly adaptive, and overly adaptive) for a total of 30 trials, following a previously implemented VP model by Fairhurst and colleagues (2013). The trial was structured as follows. In the beginning, a yellow traffic light appeared on the screen when four tones were presented through headphones at a default inter-onset interval of 500 ms (Fig.1B). Each tone consisted of an auditory pacing signal of 40 ms in duration and played as synthesized as a "bongo drum" sound. After presenting the four tones, the traffic light changed from yellow to green, and a new sequence of tones was presented. The green signal prompted the participants to start tapping the computer's spacebar with the instruction to synchronize their taps with the tones of the VP as accurately as possible and to maintain the initial tempo to the best of their ability. Participants were required to produce 23 *taps* to conclude the trial. The sequence of tones started with the base inter-onset interval (IOI) of 500 ms, which could then vary based on the level of VP adaptivity and the participant's performance. Precisely, the duration of subsequent IOIs was defined by the virtual partner through an algorithm that varied its degree of temporal adaptation, adjusting each subsequent IOI by a given proportion (α) of the amount of the asynchrony (async) of the participant's previous tap. This is the formula $t_n+1 = t_n + IOI_n + (\alpha \text{ x } async_n)$ where α – i.e., the degree of the correction - was fixed within a trial but varied across trials by assuming one of five possible values ranging from 0 (i.e., no phase correction, nonadaptive condition) to 1 (i.e., full correction, overly adaptive condition) in steps of 0.25 (i.e., α = 0, 0.25, 0.5, 0.75, 1). Thus, in the nonadaptive condition (α = 0), the IOI remained fixed at 500 ms regardless of the level of participant asynchrony. Instead, in adaptive conditions (i.e., α > 0), a negative asynchrony (i.e., the participant's tap preceded the tone) resulted in a shortening of the IOI for the next tone (t_n+1) that, thus, occurred sooner as a function of the level of α. Conversely, if the participant's tap occurred after the tone, a positive asynchrony was registered, and the IOI for the next tone was delayed. This variation simulated a flexible adaptivity and cooperation range that created differing degrees of couplings between the VP and the participant.

At the end of each condition, participants were asked to evaluate the perception of synchrony: "How much did you feel in sync with the VP?" through the visual analog scale (VAS) on a 6-point Likert scale (0 = not in sync; 5 = totally in sync). Then they evaluated their affect through the 10-item International Positive and Negative Affect Schedule Short Form (I-PANAS-SF) (Thompson, 2008), answering questions that included 5-item of Positive Affect (PA) and 5-item of Negative Affect (NA) on a 5-point Likert scale (1 = not at all; 5 = very much) (Fig.1C).

Behavioral results involved the objective measure of asynchrony between participants and VP obtained by subtracting the tap time of each tap from each tone. Asynchronies that fell outside the range of ± 125 ms were not recorded (for more details, see Repp & Keller, 2008). Additionally, we computed the absolute difference between the intertap intervals (ITIs) of each participant in the different conditions of adaptation as an intra-individual measure of the ability of the participants to keep the beat (Gebauer et al., 2016; Konvalinka et al., 2010; Repp, 2005). Participants were not informed about the interactive manipulation since they were just told to interact with the computer as a virtual partner. They were aware that the task included five interactive blocks and that at the end of each, they should have provided their evaluation of the perception of synchrony and affect.

Data analysis

The tapping task data were initially preprocessed to keep the measures of asynchrony (the difference between the tap and the tone in each trial) within +/-3 standard deviation (SD) from the average scores of each participant (resulting in removing 0.54% of the total tap-tone differences). Following previous studies (Białuńska & Dalla Bella, 2017; Mills et al., 2015), the tapping performance was analyzed in relation to the synchronization indices (asynchrony and variability) over trials across conditions.

The asynchrony measure was calculated as the absolute mean of asynchrony (the difference between the taps and the tones) as an index of the accuracy of the performance. Absolute asynchrony indicates the magnitude of the asynchrony that is independent of the earliness (negative asynchrony) or lateness (positive asynchrony) of the dynamics. Therefore, higher values indicate lower synchrony (i.e., more asynchrony), while lower scores indicate higher synchrony.

The variability of the performance was computed through the SD of the asynchrony as an index of the variability of the performance. The variability index was an inverse measure of precision indicating how unstable the tap timing was around the pacing events, where higher values indicate more instability as well as variability in tapping.

Additionally, we calculated the SD of the ITIs through the absolute difference between the tap times as a measure of the temporal variability of tapping in relation to the tones of the VP.

Linear mixed models (LMM) were used to test the effects of VP adaptivity (i.e., α levels' that change across five interactive conditions) and the borderline traits (i.e., PAI-BOR and BOR-N) on the tapping performance (asynchrony, variability and SD ITIs) as well as the subjective measures (i.e., perception of synchrony and affect). Consistent with previous studies (Fairhurst et al., 2013; Mills et al., 2019; Repp & Keller, 2008), both linear and quadratic effects of VP adaptivity were considered. With the linear effect, we observed how the dependent variables (tapping performance and subjective measures) were modulated by the variability in the VP adaptivity following a linear variation. With the quadratic effect, we observed how the dependent variables (tapping performance and subjective measures) were modulated by the variability in relation to the 'double' effect of VP adaptivity.

Indeed, VP adaptivity (linear and quadratic), borderline traits, and their interaction were listed as fixed effects. Observations were clustered among participants, with VP adaptivity (linear and quadratic) as random effects (Formula S1 in the supplement). Since conditions differed based on α levels from 0 (non-adaptive) to 1 (overly adaptative), VP adaptivity was considered a numeric variable. We were interested both in the main effects (linear and quadratic) of the level of VP adaptivity and participants' borderline traits (i.e., Model 1 Table 1, 2, 3, 4) as well as their interactions (i.e., Model 2 in Table 1, 2, 3, 4). Significant interactions were interpreted through simple slope computing of the effects of VP adaptivity at low (Mean -1SD) and high (Mean + 1SD) levels of the moderators (i.e., PAI-BOR and BOR-N).

In relation to the SD of the ITIs, we analyzed whether there was a correlation between how participants perceived synchrony during different scenarios of interaction and the SD of the ITIs (Table S2 in the supplement). Then we performed LMM to test the main effect on the SD of the ITIs of the levels of VP adaptivity (linear and quadratic) and the borderline traits (PAI-BOR and BOR-N) as well as their interaction.

Results

Mixed models were performed with borderline traits (PAI-BOR and BOR-N) and VP adaptivity (i.e., α levels), and their interaction as independent variables (fixed effects) while synchronization indices, SD of ITIs, and the subjective measures were treated as dependent variables.

First, we focused on the global score of PAI-BOR as an overall measure of BPD traits. As reported in Table 1, VP adaptivity showed significant linear and quadratic main effects on asynchrony. At increasing the level of VP adaptivity (from α = 0 to α = 1), asynchrony tended to decrease (i.e., main negative linear effect of VP adaptivity) so the participants and the VP were more synchronized, but the rate of decrement reduced from lower to higher levels of α (i.e., the main positive quadratic effect of VP adaptivity). In addition, a significant interaction between the linear effect of VP adaptivity and the PAI-BOR scores was found. The simple slope analysis showed a more negative linear effect of VP adaptivity on asynchrony for participants with lower scores of PAI-BOR (b = -0.54, SE = 0.04, *t* [203.64] = -11.98, *p* < .001), compared to participants with higher scores (b = -0.35, SE = 0.05, *t* [203.05] = -7.86, *p* < .001). As VP adaptivity increased, participants with low scores of PAI-BOR tended to be more in synchrony with the VP compared to people with high scores of PAI-BOR. Results are presented in Figure 2, panel a.

Regarding the variability (standard deviation of asynchrony, Table 1) we found a main positive quadratic effect of VP adaptivity. This means that the variability was higher for extreme values of VP adaptivity (i.e., α = 0 and α = 1) and lower for middle values of VP adaptivity (α = 0.50). Additionally, a significant interaction between the quadratic effect of VP adaptivity and PAI-BOR was found. The simple slope analysis showed that VP adaptivity had a more positive quadratic effect on variability in participants with higher scores of PAI-BOR (b = 0.11, SE = 0.01, *t* [204.11] = 11.55, *p* < .001) compared with participants with lower scores of PAI-BOR (b = 0.08, SE = 0.01, *t* [203.68] = 8.67, *p* < .001). This means that participants with higher PAI-BOR scores tended to have a more pronounced decrease in variability for VP adaptivity in the range from α = 0 to α = 0.50 and a more pronounced increase in the range from α = 0.50 to α = 1, compared to participants with lower scores of PAI-BOR. Results are depicted in Figure 2, panel b.

Regarding the subjective measures, the results on perception of synchrony, negative affect, and positive affect are reported in Table 2. In relation to the perception of synchrony, results showed the significant main effects of VP adaptivity (i.e., negative linear effect and negative quadratic effect) and the main negative effect of PAI-BOR traits. Specifically, the more VP adaptivity tended to increase, the less synchrony the participants reported (linear effect), but this decrement was more pronounced for higher scores of VP adaptivity (quadratic effect). Regarding the role of PAI-BOR, participants with higher borderline traits reported less perception of synchrony, on average, compared to participants with lower borderline traits. Regarding the negative affect (Figure 6, panel b), we found a main positive quadratic effect of VP adaptivity as well as a positive main effect of PAI-BOR traits. Participants tended to report more negative affect in response to more extreme values of VP adaptivity (i.e., α = 0 and α = 1) and lower negative affect for middle values of VP adaptivity (α = 0.50). Participants with higher borderline traits reported on average more negative affect compared to participants with lower borderline traits. Regarding positive affect (Figure 6, panel c), no significant effects were found. No significant interaction effects between VP adaptivity and PAI-BOR traits were found.

Subsequently, we focused on the results of the PAI-BOR subscale Negative Relationships (BOR-N). Regarding synchronization indices and conversely to the results of the PAI-BOR, we found a main effect of BOR-N on asynchrony and on variability but in this latter case, no interaction between VP adaptivity and BOR-N was significant (contrary to the results of PAI-BOR). These findings suggest the central dysfunctional role of traits of negative and unstable relationships on interpersonal synchrony. Results are depicted in Table 3 and presented in Figure 3 (panels a, b).

Regarding the subjective measures, BOR-N results were essentially very similar to the PAI-BOR ones. Table 4 and Figure 7 presented the results on the perception of synchrony (panel a), negative affect (panel b), and positive affect (panel c). In addition to the PAI-BOR results, we also found a significant interaction between the quadratic effect of the VP adaptivity and BOR-N on the perception of synchrony. Simple slope analysis showed that VP adaptivity had a negative quadratic effect on the perception of synchrony for participants with lower scores of BOR-N (b = -13.94, SE = 2.59, t [203.05] = -5.39, $p < .001$) but not for participants with higher scores (b = -4.44, SE = 2.57, t [203.45] = -1.72, $p = .093$).

Finally, Table 5 shows the results of the LMMs testing the association between the SD of ITIs and the PAI-BOR and BOR-N. The results revealed the significant main linear and quadratic effects of VP adaptivity on the SD of the ITIs and the main effect of PAI-BOR and BOR-N, but no significant interactions between VP adaptivity and the traits. This showed that the change in VP adaptivity modulated the variability of the tap times and that this tendency was more pronounced for higher values of VP adaptivity (quadratic effect). Then, participants with higher scores of PAI-BOR and BOR-N showed more variability during tapping than participants with lower scores of BPD traits. Results are presented in Figure 4 (PAI-BOR) and Figure 5 (BOR-N).

Discussion

The present study explored whether the levels of BPD traits (PAI-BOR and BOR-N) were associated with interpersonal asynchrony and subjective perception of synchrony and negative affect during an interaction with a virtual partner, producing varying levels of temporal adaptivity.

In relation to synchronization indices, our results showed that the change in VP adaptivity had linear and quadratic main effects on asynchrony and a main quadratic effect on the variability of asynchrony and on the variability of the ITIs. This is in line with previous studies (Fairhurst et al., 2013; Repp & Keller, 2008) and with our hypothesis, suggesting that synchrony increased with increasing VP adaptivity and that synchrony variability was most adaptive when the level of VP adaptivity was moderate ($\alpha = 0.50$) and least adaptive for extreme values of VP adaptivity ($\alpha = 0$ and $\alpha = 1$). Moreover, this suggests that interacting with a moderate partner that resembles a feeling of *"like me"* (Fairhurst et al., 2013; Konvalinka et al., 2010; Meltzoff, 2007) might functionally modulate the behavior during the interaction.

Regarding borderline traits, we found a main effect of Negative Relationships (but not of the overall measure of BPD traits, PAI-BOR) on asynchrony and the variability of asynchronies. This sustains our main hypothesis, indicating that individuals with high tendencies to establish negative and unstable relationships show more asynchrony and variability regardless of the level of VP adaptivity. Then, we also found a main effect of BPD traits and Negative Relationships on the variability in predicting the next tone. Overall those results suggest that the internal working models that underlie disturbed interactions (Bender & Skodol, 2007) and the difficulties in modulating the affect (Gunderson, 2007, 2009; Skodol et al., 2002) might drive the ability to anticipate and adapt to the other action and also to maintain stability during a synchronized interaction.

Moreover, in line with our exploratory hypothesis, we found a significant interaction between the linear effect of the VP adaptivity and the BPD traits (as well as for Negative Relationships) on asynchrony and a significant interaction between the quadratic effect of the VP adaptivity and the BPD traits on the variability of asynchrony. Specifically, the variability of the performance increased and decreased in relation to the VP adaptivity following a nonlinear trend. Individuals with high BPD traits showed a stronger decrease in variability at increasing the level of adaptivity (from $\alpha = 0$ to $\alpha = 0.5$) and a stronger increase at a higher level of VP adaptivity (from $\alpha = 0.5$ to $\alpha = 1$) compared to individuals with low levels of BPD traits. This suggests that the VP adaptivity in interaction with BPD traits influenced the variability of the performance, and a moderate level of VP adaptivity resulted in less variability. Despite such a result is in line with the view that when α is fixed at 0.5, the performance is less variable (Fairhurst et al., 2013), individuals with high BPD traits showed a higher variability compared to individuals with low BPD traits in overall variability. This suggests that individuals with high BPD traits interact with higher instability that might be associated with a reduced ability to simulate the other's action and perceive the other as "like me" than individuals with low BPD traits.

Additionally, in relation to Negative Relationships, we found no interaction on variability compared to the results with the overall BPD traits. This result suggests that the levels of Negative Relationships play a central role during synchrony and drive the interaction to higher variability regardless of how the VP adapts. This might be associated with a hyperactivation of the attachment (approach-avoidance) (Gunderson & Lyons-Ruth, 2008) underlying split view of self and other representations (Clarkin et al., 2007; Kernberg & Caligor, 2005), feelings of rejection, and abandonment (Gunderson, 2007).

In relation to the subjective experience, we found a main linear and quadratic effect of VP adaptivity on the perception of synchrony, so at increasing the level of VP adaptivity participants perceived low synchrony, and this decrement was more pronounced from the middle ($\alpha = 0.25$) to high ($\alpha = 1$) levels of VP adaptivity levels. Then, as we expected, we found a main effect of BPD traits on the perception of synchrony, meaning that participants perceived lower synchrony in relation to high BPD features. Moreover, we found a significant interaction between the quadratic effect of VP adaptivity and low levels of Negative Relationships, indicating that there was a strong and pronounced decrease in the perceived synchrony at increasing the VP adaptivity, while individuals with high Negative Relationships showed a linear decrease.

Specifically, we observed that the perception of synchrony was not aligned with the measure of asynchrony. For instance, when the VP was overly adaptive ($a = 1$) participants reported perceiving low synchrony compared to other levels of VP adaptivity, but the trend of asynchrony was the inverse. Moreover, the perception of synchrony was negatively associated with the variability of ITIs, meaning that participants may have been tracking variability and perceiving this as a strength of synchrony rather than how well they coordinated with the VP. However, previous studies have shown that people synchronize better when they are better able to predict their partner's action, which is evidenced by lower variability of their own actions (Gebauer et al., 2016; Pecenka et al., 2011). In this sense, we speculate that better synchrony may have been achieved through better prediction of the VP's next tone, and, consequently, less hyper-adaptability and variability in ITIs. Hence, one mechanism that may be impaired in people with high BPD features is the ability to predict the timing of others' future behavior correctly.

In relation to the negative affect, we found a main quadratic effect of the VP adaptivity on the negative affect, suggesting a pronounced modulation of the affect concerning the change of the VP adaptivity from non-adaptive ($\alpha = 0$) to overly adaptive ($\alpha = 1$). Then, in line with our main hypotheses, we found a main effect of BPD traits on the negative affect. This is in line with previous studies (Carpenter & Trull, 2013; Hepp et al., 2017) and suggests that individuals with high BPD traits compared to individuals with low BPD traits interacted with higher negative affect as a component of emotional dysregulation and a result of high emotion sensitivity that might be rooted in an invalidated early environment (Linehan, 1993).

Taken together, we observed that the higher interpersonal vulnerabilities and emotional dysregulation (Bender & Skodol, 2007; Linehan, 1993) in relation to individuals with high BPD traits could interfere with the ability to anticipate and adapt to the other's actions as well as with the experience of the interaction. Notably, individuals with high BPD traits showed higher asynchrony and variability compared to individuals with low BPD traits and higher variability in predicting the other's action (ITIs). Specifically, high levels of Negative Relationships compared to low levels of Negative Relationships were associated with high variability in asynchronies regardless of the VP's degree of responsiveness and adaptation. Such relevant findings indicate that high interpersonal instability and disturbed interactions might play a central role during synchrony. Additionally, the perception of synchrony was reduced in individuals with high BPD traits vs. low levels of BPD traits but aligned with the higher variability as a mechanism that damages interpersonal synchrony. Then the higher negative affect seemed to be not modulated by the VP adaptivity and negatively impacted the emotional experience in relation to individuals with high BPD traits compared to those with low levels of BPD traits.

Those findings sustain the view that the distorted representations of self and other (Caligor et al., 2023; Kernberg & Caligor, 2005) might lead to impairments in co-representing others' actions, leading to reduced mutual adaptation (Heggli, Cabral, et al., 2019). In this sense, the core pathological features of BPD could interfere with the main mechanisms of mutual adaptation which sustain interpersonal synchrony. Along these lines, we speculate that individuals with high BPD traits might develop dysfunctional internal working models that hamper the possibility of synchronizing and regulating emotions. Disturbed experiences of interactive contingency mother-infant (Beebe & Lachmann, 2013; Lyons-Ruth & Spielman, 2004) and a reduced capacity to mentalize (Fonagy & Bateman, 2008) in the context of a dysfunctional attachment (as a precursor of BPD symptoms) (Fonagy, 2002) could play a role in interpersonal synchrony even when the adaption was moderately ($\alpha = 0.5$). Then, our findings suggest that individuals with high BPD traits were associated with a reduced perception of synchrony and high negative affect compared to individuals with low levels of BPD traits. This enhances the idea that the higher sensitivity to rejection and mistrust (Fertuck et al., 2018; Minzenberg et al., 2006) might play a role during synchrony leading to a negative emotional experience.

Conclusion

In conclusion, our results reveal that interpersonal disturbances and emotional dysregulation (Lieb et al., 2004; Gunderson, 2008) related to individuals with high BPD traits might interfere with the social cognitive processes implicated in coordination processes. Consequently, such impairments might lead to higher asynchrony and a negative experience of synchrony. However, these findings should be interpreted in the context of their limitations. First, we recruited a nonclinical sample, and BPD traits were tested with self-report, so the generalizability of the results is uncertain. Second, the mathematically derived VP response allows high control of the conditions. Third, we measured interpersonal synchrony within a human-computer interaction so the task could be limited in ecological validity.

However, our results indicate that synchrony could be modulated by interpersonal functioning, suggesting that it might have a potential role during interventions in building the therapeutic relationship. Consistent with that, we encourage further research to explore how BPD symptoms could be implicated during synchronized interaction as an extension of our results. Further, future studies should address the need to investigate better the mechanisms underpinning interpersonal coordination in psychopathology and among clinical populations.

Tables and Figures

Table 1. Results of mixed models on synchronization indices (asynchrony and variability): main effects and interaction between VP adaptivity (linear and quadratic) and PAI-BOR

	Asynchrony (Absolute mean of asynchrony)				Variability (Standard deviation of asynchrony)			
	Model 1		Model 2		Model 1		Model 2	
	b	*p*	b	*p*	b	*p*	b	*p*
Fixed Effects								
VP adaptivity_linear	-0.455	< .001	-0.903	< .001	0.016	.140	0.020	.708
VP adaptivity _quadratic	0.156	< .001	0.310	.011	0.104	< .001	0.034	.334
PAI-BOR	0.003	.127	0.002	.357	0.001	.156	0.001	.056
VP adaptivity _linear * PAI-BOR			0.204	.004			-0.001	.941
VP adaptivity _quadratic * PAI-BOR			-0.070	.196			0.032	.042
Random Effects								
VP adaptivity_linear	0.29		0.28		0.05		0.05	
VP adaptivity _quadratic	0.15		0.15		0.02		0.02	
LogLik.	17166.49		17167.13		23196.23		23102.38	
AIC	-34310.99		-34308.26		-46190.45		-46178.76	
Marg. R^2 /Cond. R^2	0.079 / 0.657		0.079 / 0.656		0.040 / 0.485		0.043 / 0.486	
Model comparison	$X^2 = 5.4225$, $p = .066$				$X^2 = 5.577$, $p = .061$			

Note: PAI-BOR= overall measure of borderline traits; Model 1 = only main effect: VP adaptivity (linear and quadratic) and PAI-BOR; Model 2= Model 1 + interaction between VP adaptivity (linear and quadratic) and PAI-BOR; Marg. R^2 / Cond. R^2 = Marginal R^2 / Conditional R^2 computed based on (Nakagawa & Schielzeth, 2013) approach.

Table 2. Results of mixed models on subjective measures: main effects and interaction between VP adaptivity (linear and quadratic) and PAI-BOR on the perception of synchrony and negative and positive affect

	Perception of synchrony				**Negative affect**				**Positive affect**			
	Model 1		**Model 2**		**Model 1**		**Model 2**		**Model 1**		**Model 2**	
	b	***p***	**b**	***p***	**b**	***p***	**b**	***p***	**b**	***p***	**b**	***p***
Fixed Effects												
VP adaptivity_linear	-20.758	< .001	-23.699	.023	1.317	.102	6.438	.098	-1.449	.221	-2.155	.708
VP adaptivity _quadratic	-9.127	< .001	-23.665	.008	1.992	.004	2.612	.440	-0.896	.461	5.212	.362
PAI-BOR	-0.322	.023	-0.297	.038	0.309	< .001	0.307	< .001	-0.014	.903	-0.022	.849
VP adaptivity_linear* PAI-BOR			1.339	.774			-2.341	.179			0.322	.900
VP adaptivity_quadratic* PAI-BOR			6.643	.098			-0.283	.851			-2.781	.277
Random Effects												
VP adaptivity_linear	884.00		888.03		125.19		0.19		269.39		270.78	
VP adaptivity _quadratic	648.83		643.64		91.90		87.81		270.51		270.26	
LogLik.	-5333.822		-5327.68		263.482		-723.4083		-2583.945		-2579.617	
AIC	10689.64		10681.36		-504.964		1472.817		5189.891		5185.235	
Marg. R^2/Cond. R^2	0.071 / 0.838		0.070 / 0.838		0.088 / 0.843		0.262 / NA		0.001 / 0.882		0.001 / 0.883	
Model comparison	X^2 = 2.791, *p* = .247				X^2 = 1.820, *p* = .402				X^2 = 1.210, *p* = .546			

Note: PAI-BOR= overall measure of borderline traits; Model 1 = only main effect: VP adaptivity (linear and quadratic) and PAI-BOR; Model 2= Model 1 + interaction between VP adaptivity (linear and quadratic) and PAI-BOR; Marg. R^2 / Cond. R^2 = Marginal R^2 / Conditional R^2 computed based on (Nakagawa & Schielzeth, 2013) approach.

Table 3. Results of mixed models on synchronization indices (asynchrony and variability): main effects and interaction between VP adaptivity (linear and quadratic) and BOR-N (Negative Relationships)

	Asynchrony (Absolute mean of asynchrony)				**Variability (Standard deviation of asynchrony)**			
	Model 1		**Model 2**		**Model 1**		**Model 2**	
	b	***p***	**b**	***p***	**b**	***p***	**b**	***p***
Fixed Effects								
VP adaptivity_linear	-0.455	< .001	-0.726	<.001	0.016	.142	0.016	.721
VP adaptivity _quadratic	0.156	< .001	0.319	.002	0.104	< .001	0.074	.015
BOR-N	0.004	.016	0.003	.044	0.001	.010	0.001	.008
VP adaptivity _linear * BOR-N			0.119	.043			-0.0001	.994
VP adaptivity _quadratic* BOR-N			-0.072	.109			0.013	.318
Random Effects								
VP adaptivity_linear	0.29		0.28		0.05		0.05	
VP adaptivity _quadratic	0.15		0.15		0.02		0.02	
LogLik.	17167.97		17166.58		23107.96		23102.05	
AIC	-34313.94		-34307.16		-46193.92		-46178.09	
Marg. R^2 /Cond. R^2	0.087 / 0.657		0.086 / 0.656		0.047 / 0.485		0.049 / 0.486	
Model comparison	$X^2 = 5.509$, $p = .063$				$X^2 = 1.074$, $p = .584$			

Note: BOR-N= overall measure of borderline traits; Model 1 = only main effect: VP adaptivity (linear and quadratic) and PAI-BOR; Model 2= Model 1 + interaction between VP adaptivity (linear and quadratic) and PAI-BOR; Marg. R^2 / Cond. R^2 = Marginal R^2 / Conditional R^2 computed based on (Nakagawa & Schielzeth, 2013) approach.

Table 4. Results of mixed models on subjective measures: main effects and interaction between VP adaptivity (linear and quadratic) and BOR-N (Negative Relationships) on the perception of synchrony and negative and positive affect

	Perception of synchrony				Negative affect				Positive affect			
	Model 1		Model 2		Model 1		Model 2		Model 1		Model 2	
	b	***p***	**b**	***p***	**b**	***p***	**b**	***p***	**b**	***p***	**b**	***p***
Fixed Effects												
VP adaptivity_linear	-20.776	< .001	-18.858	.035	1.317	.101	5.186	.123	-1.444	.221	-5.706	.250
VP adaptivity_quadratic	-9.118	< .001	-28.464	< .001	1.992	.004	2.070	.479	-0.869	.461	1.850	.708
BOR-N	-0.265	.023	-0.238	.044	0.217	< .001	0.217	< .001	-0.0036	.971	-0.002	.982
VP adaptivity_linear * BOR-N			-0.845	.835			-1.704	.236			1.876	.377
VP adaptivity_quadratic * BOR-N			8.522	.009			-0.034	.978			-1.198	.571
Random Effects												
VP adaptivity_linear	883.43		888.19		125.23		124.97		269.39		269.70	
VP adaptivity_quadratic	648.74		629.93		91.89		92.38		270.53		271.47	
LogLik.	-5334.055		-5326.285		259.4524		262.577		-2584.143		-2580.232	
AIC	10690.11		10678.57		-496.9048		-499.154		5190.287		5186.464	
Marg. R^2 /Cond. R^2	0.071 / 0.838		0.071 / 0.838		0.064 / 0.843		0.065 / 0.843		0.001 / 0.882		0.001 / 0.883	
Model comparison	$X^2 = 6.921$, $p = .031$				$X^2 = 1.439$, $p = .486$				$X^2 = 1.122$, $p = .570$			

Note: BOR-N= overall measure of borderline traits; Model 1 = only main effect: VP adaptivity (linear and quadratic) and PAI-BOR; Model 2= Model 1 + interaction between VP adaptivity (linear and quadratic) and PAI-BOR; Marg. R^2 / Cond. R^2 = Marginal R^2 / Conditional R^2 computed based on (Nakagawa & Schielzeth, 2013) approach.

Table 5. Results of mixed models on Standard Deviation of ITIs: main effect and interaction

	Standard Deviation of ITIs (SD ITIs)			
	Model 1		**Model 2**	
	b	***p***	**b**	***p***
Fixed Effects				
VP adaptivity_linear	-0.304	< .001	-0.460	.086
VP adaptivity _quadratic	0.480	< .001	0.286	.175
PAI-BOR	0.006	.022	0.006	.020
VP adaptivity _linear * PAI-BOR			0.071	.551
VP adaptivity _quadratic* PAI-BOR			0.088	.348
Random Effects				
VP adaptivity_linear	0.49		0.50	
VP adaptivity _quadratic	0.26		0.26	
LogLik.	13358.36		13356.46	
AIC	-26694.72		-26686.91	
Marg. R^2 /Cond. R^2	0.053 / 0.452		0.054 / 0.452	
Model comparison	X^2 = 1.540, p = .463			

	Standard Deviation of ITIs (SD ITIs)			
	Model 1		**Model 2**	
	b	***p***	**b**	***p***
Fixed Effects				
VP adaptivity_linear	-0.304	< .001	-0.460	.106
VP adaptivity _quadratic	0.480	< .001	0.286	.231
BOR-N	0.007	.001	0.006	< .001
VP adaptivity _linear * BOR-N			0.071	.755
VP adaptivity _quadratic* BOR-N			0.088	.137
Random Effects				
VP adaptivity_linear	0.49		0.50	
VP adaptivity _quadratic	0.26		0.26	
LogLik.	13360.9		13359.15	
AIC	-26699.79		-26692.29	
Marg. R^2 /Cond. R^2	0.061 / 0.451		0.064 / 0.452	
Model comparison	X^2 = 2.624, p = .269			

Note: PAI-BOR= overall measure of borderline traits; Model 1 = only main effect: VP adaptivity (linear and quadratic) and PAI-BOR; Model 2= Model 1 + interaction between VP adaptivity (linear and quadratic) and PAI-BOR; Marg. R^2 / Cond. R^2 = Marginal R^2 / Conditional R^2 computed based on (Nakagawa & Schielzeth, 2013) approach.

Note: BOR-N= overall measure of Negative Relationships; Model 1 = only main effect: VP adaptivity (linear and quadratic) and BOR-N; Model 2= Model 1 + interaction between VP adaptivity (linear and quadratic) and BOR-N; Marg. R^2 / Cond. R^2 = Marginal R^2 / Conditional R^2 computed based on (Nakagawa & Schielzeth, 2013) approach.

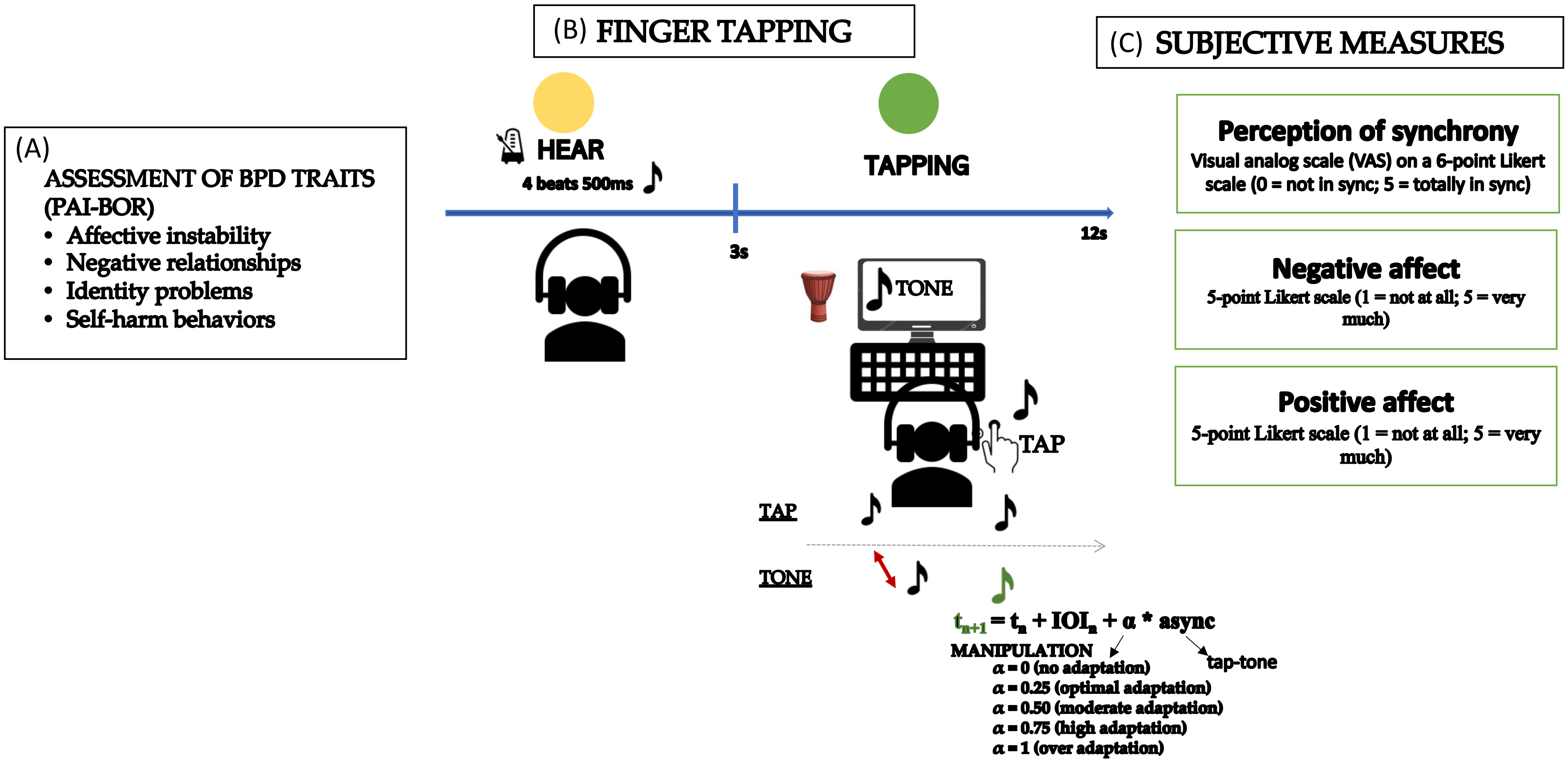
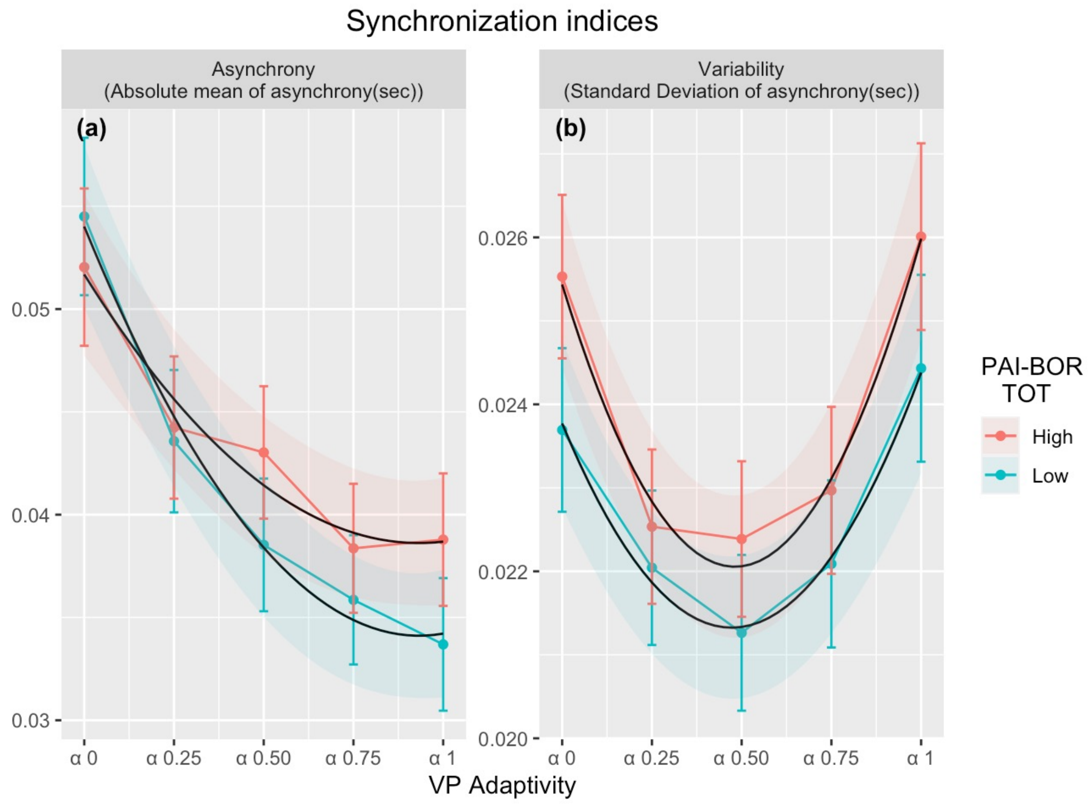


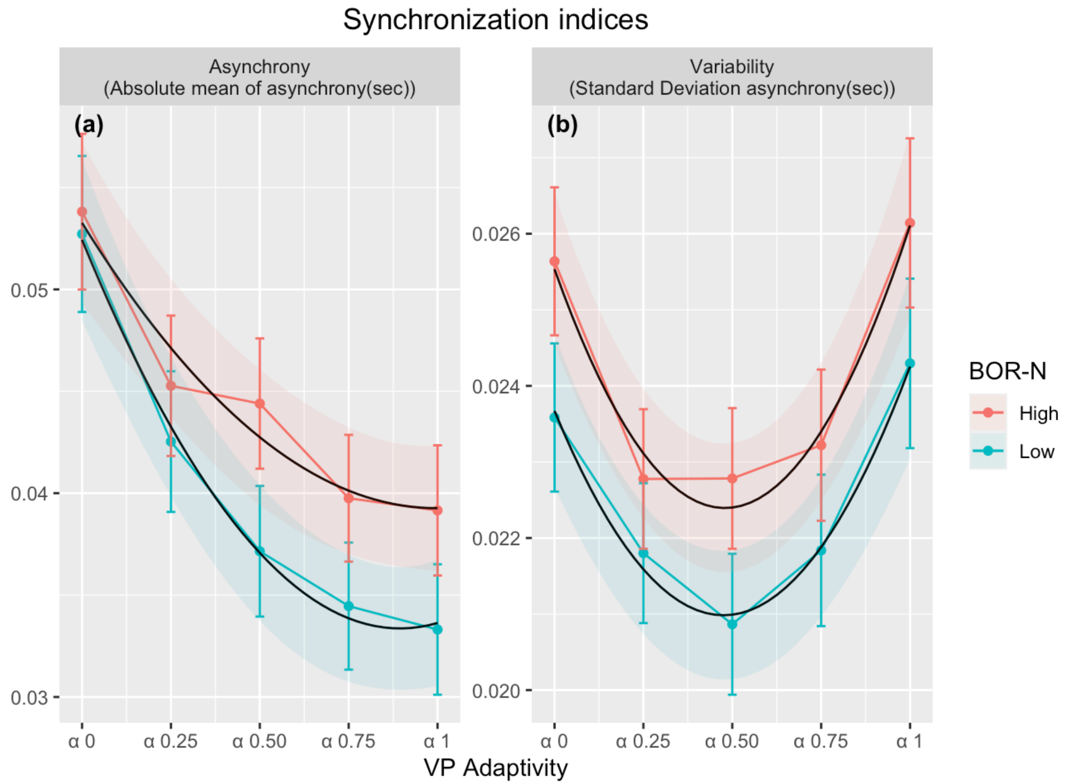
Figure 1. The experimental procedure. (A) Participants were asked to fill out a personality self-report (PAI-BOR) provided online. (B) They executed a finger tapping task. This is the timeline of the trial. Participants heard four isochronous 50 ms initiation tones while showing a yellow dot on the screen. In this phase they were asked to hear and the sound without tapping (no interaction "computer condition"). Then from the fifth tone when a green light appeared, participants were instructed to tap in synchrony with the variable adaptive pacing signal (tone) that was programmed to vary its tone onsets by a fraction (α) of the measured asynchrony. We manipulated the temporal adaptation of the VP to the taps of the participants by locally modifying its base inter-onset interval (500 ms) depending on the level of phase correction (α: from non adaptive to overly adaptive) employed. (C) Then after the sequence of 6 trials in each one of the 5-randomized blocks differentiated by the level of α, participants were asked to fill out two subjective measures (perception of synchrony and affect).

Figure 2. Effect of VP adaptivity, PAI-BOR, and their interaction on the synchronization indices



Note: Confidence bar and bands represent the 95% confidence interval around point estimates of the means.

Figure 3. Effect of VP adaptivity, BOR-N, and their interaction on the synchronization indices



Note: Confidence bar and bands represent the 95% confidence interval around point estimates of the means.

Figure 4. Effect of VP adaptivity, PAI-BOR and their interaction on SD ITIs

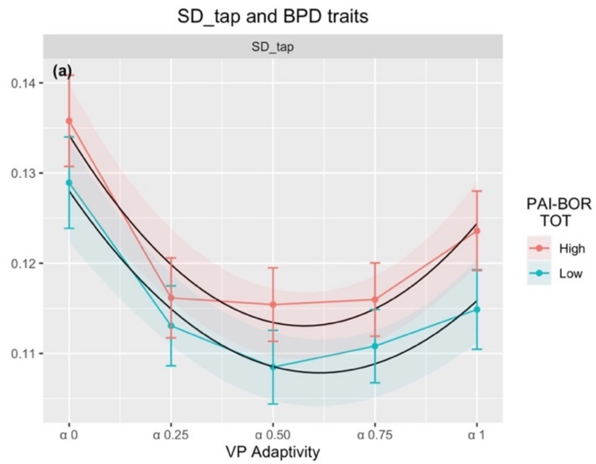
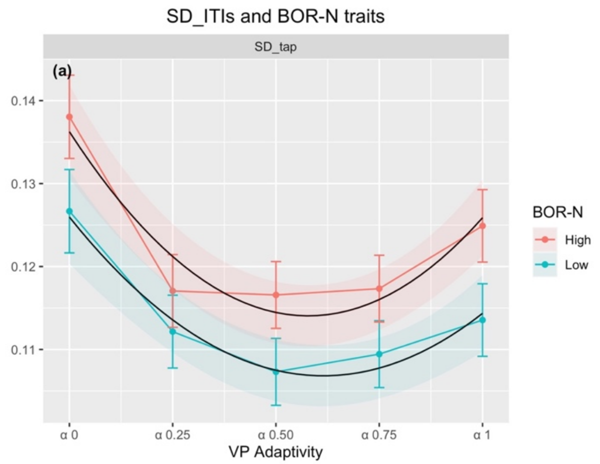
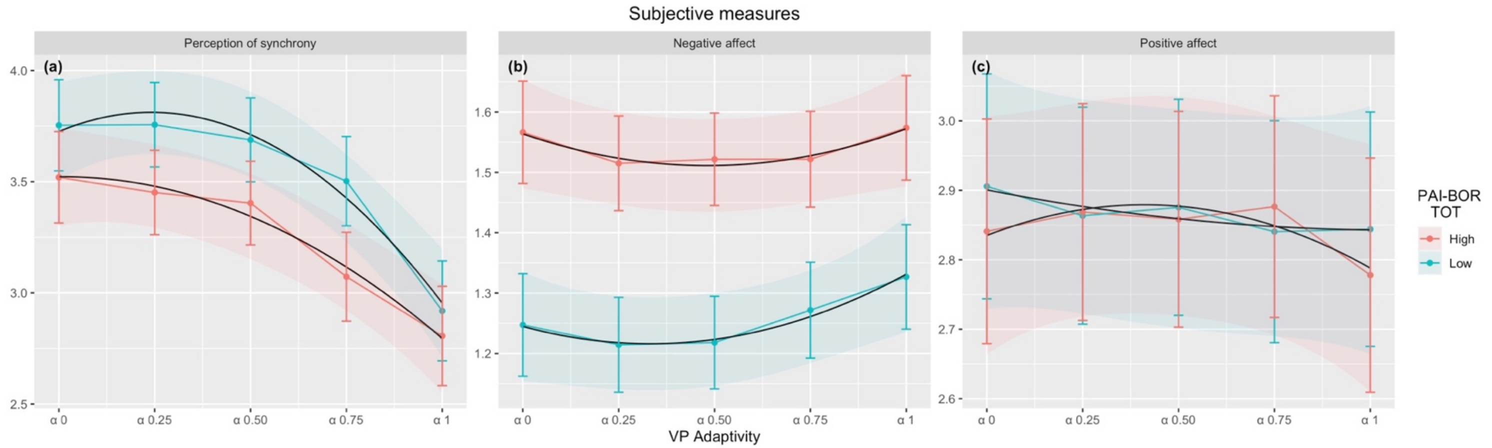


Figure 5. Effect of VP adaptivity, BOR-N, and their interaction on SD ITIs



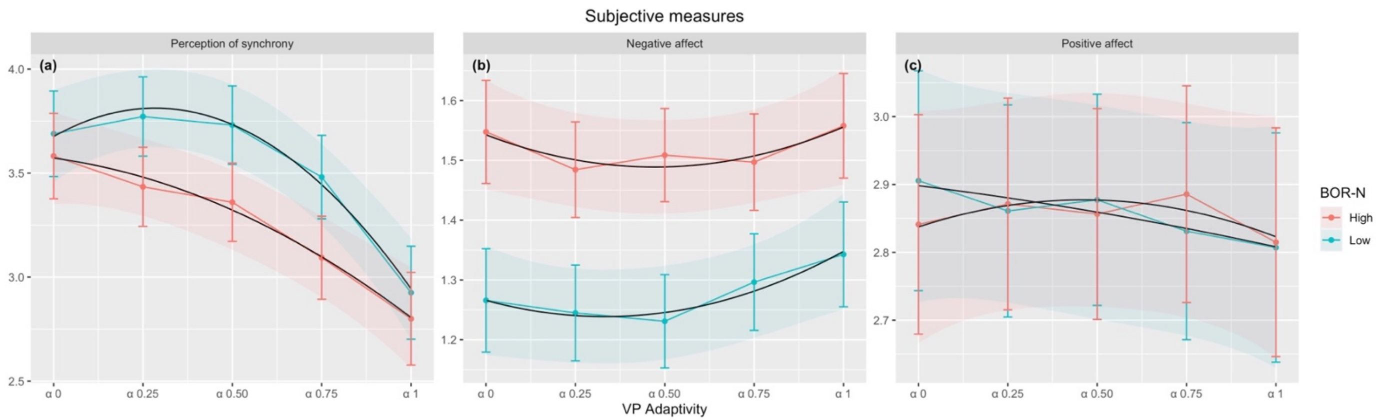
Note: Confidence bar and bands represent the 95% confidence interval around point estimates of the means.

Figure 6. Effect of VP adaptivity, PAI-BOR and their interaction on subjective measures (perception of synchrony and negative and positive affect)



Note: Confidence bar and bands represent the 95% confidence interval around point estimates of the means.

Figure 7. Effect of VP adaptivity, BOR-N and their interaction on subjective measures (perception of synchrony and negative and positive affect)



Note: Confidence bar and bands represent the 95% confidence interval around point estimates of the means.

CHAPTER 2

Altered mu suppression? The role of high borderline personality traits *(in preparation)*

Gregorini, C., De Carli, P., Petilli, M., Lomoriello, A., Preti, E., Zamm, A., & Konvalinka, I.

ABSTRACT

Interpersonal coordination processes rely upon the ability to anticipate and adapt to one's own and other actions during social interactions. Mutual adaptation strengthens interpersonal synchrony to emerge as a potentially beneficial relational phenomenon. However, the neural mechanisms underlying the association between pathological personality features and interpersonal synchrony have not been largely investigated. Here, we aimed to fill this gap by testing how BPD traits may modulate neural mechanisms during an interaction with self and other interactions. We employed a synchronized finger-tapping task and measured EEG from participants (N = 50) who interacted with a virtual partner (VP) in the 'other' conditions with varying a degree of adaptivity or with no interaction partner in the individual (self) condition. The perceptions of synchrony and cooperation were rated after each interaction. BPD traits were assessed using the Personality Assessment Inventory Borderline Features Scale. At the neural level, we found a suppression at mu rhythm 9-13 Hz over the sensorimotor areas across all the conditions. However, a main effect of BPD traits was found at 10Hz, suggesting a reduced mu suppression at this specific component. Then, at increasing levels of VP adaptivity, lower perceptions of synchrony and cooperation were found, while BPD significantly affected the perception of cooperation. These results suggest that individuals with high BPD traits show a deficit in self and other sensorimotor integration compared to individuals with low BPD traits. Further research is encouraged to investigate which mechanisms underlie mu suppression in clinical populations.

Introduction

During social interactions, human beings naturally coordinate their movements with each other (Bernieri & Rosenthal, 1991; Schmidt & O'Brien, 1997; Sebanz et al., 2006). Interpersonal coordination depends on the interplay of different mechanisms such as sensorimotor sharing, mental representation, and affective processes (Vesper et al., 2017; Keller et al., 2014). Additionally, some complementary features might be implicated such as perspective-taking, co-representing other actions, and the ability to anticipate and adapt to other actions. Those processes underpin the mental representations of self and other actions achieved by internal simulation of co-representation of the partner's actions (Dumas, 2011; Dumas, Laroche, et al., 2014; Gallotti & Frith, 2013; Kourtis et al., 2019; Novembre et al., 2012; Vesper et al., 2013). From a cognitive perspective, people actively participate in their interactions by activating the action-perception loop (Hari & Kujala, 2009) as a pathway that sustains interaction with others. At the neural level, during the observation or the imagination, a suppression at the alpha range (8-13 Hz) and beta range (15-30 Hz) could be detected over sensorimotor areas (Muthukumaraswamy et al., 2004; Oberman et al., 2005; Pineda, 2005; Hari et al., 2000; Hari, 2006). Such deflection or de-synchronization is related to a peak at 10 Hz within the alpha rhythm or 20 Hz in the beta rhythm. This deflection has been called "mu rhythm" (Gastaut, 1952) and reflects the disinhibition of the sensorimotor system during planning, execution, perception, and predictions of one's own and others' actions (Hari, 2006; Pfurtscheller & Lopes da Silva, 1999; Pineda, 2005). Moreover, mu-rhythm suppression has been proposed to reflect common coding of perception and action (Hari, 2006; Hari & Kujala, 2009). However, the role of psychopathological features in modulating such activity remains largely unknown.

Borderline Personality Disorder (BPD) is a severe psychiatric condition characterized by profound instability in affectivity, identity, and relationships (Lieb et al., 2004; Skodol et al., 2002). From clinical research and a theoretical perspective, individuals with BPD features have been associated with impairments in mentalization (Fonagy et al., 2003; Fonagy & Luyten, 2009) as "the ability to think about one's own thoughts and feelings and those of others as one attempts to predict and understand behavior" (Fonagy, 1991) that might be rooted in insecure-disorganized attachment relationships (Agrawal et al., 2004; Gunderson & Lyons-Ruth, 2008). Such cognitive and affective impairments damage the cortical structures related to regulating affective arousal and, in turn, the cognitive control (Fonagy & Bateman, 2008; Schore, 2001, 2022). Several studies (see Herpertz et al., 2018; Mak & Lam, 2013 for reviews) have defined the neurocognitive profile of BPD patients by analyzing the neural correlates of the well-known emotional dysregulation and social-cognitive processes. fMRI studies showed abnormalities in the front-limbic network (amygdala and insula) and front-brain regions related to regulatory control processes (anterior cingulate cortex, medial prefrontal cortex, orbitofrontal cortex, dorsolateral prefrontal cortex) (Lieberman et al., 2007; Lamm et al., 2016). Moreover, some research has identified dysfunctional patterns in the frontoparietal mirror neuron network that relies upon the Shared Representational (SR) (Decety, 2010; Decety & Chaminade, 2003) and Mental State Attribution (MSA) systems (Ripoll et al., 2013) that are required for an accurate sensorimotor simulation. Importantly, an integrated activity of the neural mechanisms helps to understand the perspective of the other and enables a distinction and integration of the self and the other (De Meulemeester et al., 2021). However, the interpersonal impairments of BPD have been associated with an imbalance between those neural networks (Luyten & Fonagy, 2015; Ripoll et al., 2013) that might be affected by emotional dysregulation and by the early social interactions (Fonagy et al., 2007) such as the quality and the timing of the caregiver's responses to infant's reactions (Beebe et al., 2008; Beebe & Lachmann, 2013). Some studies have found that self-other control and self-other conflation in BPD refer to a hypoactivation of the SR that coincides with hyperactivation of MSA or vice-versa (Luyten and Fonagy, 2015; Ripoll et al., 2013). This resembles a cognitive imbalance between the processes addressed to the prefrontal cortex and TPJ (Quesque & Brass, 2019) that could result in unstable interpersonal relationships and dysfunctional mechanisms of social cognition.

To the best of our knowledge, only one study has investigated mu suppression in BPD patients during an observation task (Martin et al., 2017). The authors found suppression of mu activity in BPD patients like the control group during action observation. However, such activity strongly decreased just as the observed action contained no additional goal-directed or reward-associated information (Martin et al., 2017). Concerning EEG monitoring protocols (such as resting state, hyperventilation, or photic stimulation), some studies comparing BPD-medicated or non-medicated BPD patients vs. the control group showed no significant abnormalities (see Ruocco & Carcone, 2016 for a review). More studies used event-related potentials during interactive tasks to investigate how the social cognitive dysfunctions of BPD patients could interfere with the interaction. These findings suggested that patients with BPD showed poorer auditory integration as reflected by a lower amplitude and potentially longer latency of the P300 wave, which is consistent with studies of patients with cognitive dysfunction. Those patients showed smaller feedback-related negativity after receiving information about monetary loss, reflecting a reduced capacity to incorporate information about decisions for future choices (Schuermann et al., 2011; Vega et al., 2013). Furthermore, another limited number of studies provided an EEG spectral analysis in relation to BPD (Boutros et al., 2003). For instance, theta activity was found to be significantly correlated with pain ratings in BPD patients with and without self-injurious behavior (Russ et al., 1999), while Verkes and colleagues found the absence of neural activity for 24-hour periodicity in BPD patients with suicidal ideations and impulsiveness (Verkes et al., 1996).

Additionally, in relation to psychopathology, studies considered the role of mu suppression as a neurophysiological correlate of the mirror neuron system (MNS) and have been investigated in different clinical populations. For instance, some studies using EEG (Bernier et al., 2007; Oberman et al., 2005, 2007) and fMRI (Dapretto et al., 2006; J. H. Williams et al., 2001; J. H. G. Williams et al., 2006) found a lack of mu modulation during action observation in individuals with autism spectrum disorder (ASD) providing evidence that individuals with ASD could show dysfunction of simulation networks. Conversely, some EEG studies reported no mu dysfunction in ASD (Fan et al., 2010; Lefebvre et al., 2018; Raymaekers et al., 2009) suggesting that the results are mixed (Dumas, Soussignan, et al., 2014; Hamilton, 2012) and need more investigations.

Here, we will employ a synchronized finger-tapping study similar to the task we used in study presented in Chapter 1 (Gregorini et al., under review). In the original version of the task, participants were asked to tap and try to stay in synchrony with the sound (tone) of a virtual partner (VP) that has been manipulated in time according to different degrees of temporal adaptivity from non-adaptive to overly adaptive (Fairhurst et al., 2013). Specifically, the sound changed in time in relation to the inter-onset intervals (IOIs) occurring at different moments in time in relation to the direction of the previous asynchrony. Consistent with this, when the VP interacts with no adaptivity, the tone was regular and proceeded as a metronome every 500 ms, but when the degree of adaptation was different from zero (i.e, 0.25, 0.50) the sound was presented later or earlier in relation to the previous asynchrony (difference between the tap of the participant and the tone of the VP) (Fairhurst et al., 2013; Repp & Keller, 2008; Van Der Steen & Keller, 2013). Such paradigm and the experimental manipulation allowed us to investigate how the adaptation and anticipation processes implicated during coordination (Bolt & Loehr, 2017; Vesper et al., 2013) might be hampered by the level of specific psychopathological interpersonal features.

In the current study, we differentiated between two types of conditions: the other interactive - while participants had to synchronize with the variable adaptive sound produced by the VP - and the individual conditions - where participants heard their self-generated taps and were instructed to tap alone. During the interactive conditions, the VP responded to the participants' taps as a function of a specific parameter α (phase correction - nonadaptive, moderately adaptive, overly adaptive) in relation to the previous difference tap-tone. We explored the role of BPD traits in modulating mu suppression during an interaction with a variable adaptive partner (other) or with no interaction partner in an individual condition (self). We expected low sensorimotor integration rooted in a reduced action-perception loop reflected by reduced mu suppression (9-13Hz) in individuals with high BPD traits vs. low BPD traits. Such neural impairments might be related to the altered representation and co-representation of self and others (Kernberg & Caligor, 2005) and mentalizing impairments (Fonagy & Luyten, 2009; Nolte et al., 2013) rooted in disorganized experiences characterized by reduced ‘markedness’ (Gergely & Watson, 1999). In addition, based on our previous study (Gregorini et al., under review; Chapter 1) and the empirical findings (Carpenter et al., 2013; Minzenberg et al., 2006; Seres et al., 2009), we expected that individuals with high BPD traits would perceive low synchrony and cooperation.

Materials and methods

Participants and procedure

50 participants (23 females, 46%, 27 males, 54%; M*age* = 24.3, SD*age* = 2.56) were recruited at the Technical University of Denmark (DTU) using flyers at campus sites and online advertisement boards. All participants reported basic English language skills, normal hearing, normal or corrected-to-normal vision, and no current use or history of psychotropic medication. All participants provided informed consent prior to the experiment and received financial compensation for their participation. The study was conducted according to the Declaration of Helsinki and was approved by DTU Compute’s Institutional Review Board (COMP-IRB-2023-01). After assessment of BPD traits through the Personality Assessment Inventory-Borderline Scale (PAI-BOR) (Morey, 1991) via SurveyXact, participants were invited to sit at an individual computer, and they engaged in a synchronized finger-tapping study while EEG was recorded. The task consisted of four different conditions: 3 interactive conditions (hear *other*) where the participants interacted with and only heard generated sounds from a virtual partner (VP, generated by the computer) with varying degrees of adaptability (non-adaptive, moderately adaptive, or overly adaptive) (see Fairhurst et al., 2013), and an individual control condition (hear *self*) in which the participants heard only their self-generated taps. At the end of each interaction, participants were asked to rate their perception of synchrony and cooperation. The experimental process is presented in Figure 1.

Task

The experimental finger-tapping task was programmed in Matlab R2020b (Mathworks Inc., Natick, MA, USA) using Psychtoolbox (version 3.0.17; Brainard, 1997; Kleiner et al., 2007; Pelli, 1997). The procedure of the finger-tapping task was developed following previous literature (Gregorini et al., under review; Chapter 1; Repp, 2005; Repp & Keller, 2008; Vorberg & Wing, 1996).

The experiment consisted of 120 trials across four different conditions. The interactive conditions were subdivided into 3 blocks which varied by the levels of VP adaptivity (alpha). In all the blocks, the trials were initiated by 4 steady beats (hear) from the computer at a steady tempo of 500ms (120 bpm). Then during tapping, participants heard the manipulated auditory stimulus produced by the computer (other), and the instruction was to stay in synchrony with the sound that they heard as precisely as possible. In these conditions, the sequence of tones varied based on the level of VP adaptability and the participant's performance. Precisely, the duration of subsequent IOIs was defined through an algorithm adjusting each subsequent IOI by a given proportion (α) of the amount of the asynchrony (async) of the participant's previous tap: $t_{n+1} = t_n + IOI_n + (\alpha \text{ x } async_n)$ where α – i.e., the degree of the correction - was fixed within a trial but varied across trials by assuming one of three possible values ranging from 0 (i.e., no phase correction, nonadaptive condition) to 1 (i.e., full correction, overly adaptive condition) in steps of 0.25 (i.e., α = 0, 0.5, 1; jittered ~ .02). For example, in the adaptive conditions (i.e., α > 0), a negative asynchrony (i.e., the participant's tap preceded the tone) resulted in a shortening of the IOI for the next tone (t_n+1) that, thus, occurred sooner as a function of the level of α. Conversely, if the participant's tap occurred after the tone, a positive asynchrony was registered, and the IOI for the next tone was delayed. This variation simulated a flexible adaptivity and cooperation range that created differing degrees of couplings between the VP and the participant. Such manipulation allowed to vary the time of the sound in relation to the participants' previous taps to reduce asynchrony during the interaction. In the individual control condition, the participants heard only their self-generated taps during tapping with the instruction to keep the beat that they heard as precisely as possible. Before the experiment, the participants were told that they would interact with different real partners during the interactive conditions who were seated in separate rooms. Audio from the computer was delivered to participants via EEG-compatible earbuds (ER2C Tubal Insert Earphones, Etymotic Research Inc., USA). The participants were asked to sit still and avoid blinks and exploratory eye movements during tapping as much as possible.

Subjective measures

After each interactive condition ("hear other") participants were asked to rate their perception of synchrony and cooperation with the VP. Participants were instructed to rate: *"How much synchrony did you feel during the interaction?"* on a 5-point scale Likert scale (1 = low; 5 = high) and "*How much cooperation did you feel during the interaction?"* on a 5-point Likert scale (1 = low; 5 = high).

EEG recordings

EEG was recorded using the 64-channel Biosemi (Amsterdam, The Netherlands) ActiveTwo EEG system in a 10-20 configuration, at a sampling frequency of 2kHz. Data were recorded in ActiView (v. 900). An EEG cap with 64 channels was positioned such that the Cz electrode was centered on the head at the midpoint between the nasion and inion, and the left and right ear. Conductive gel (Signal Gel Electrode Gel, Parker Laboratories, Farfield, NJ) was used to reduce the skin-electrode impedance, and the offset was kept below 20 mV. Four EOGs electrodes were placed: two recorded the vertical electrooculogram (VEO) placed 1 cm above and 1 cm below the left eye, and two the horizontal electrooculogram (HEO) for the left and right eyes.

Personality Assessment

To assess BPD features, participants completed the Personality Assessment Inventory-Borderline Scale (PAI-BOR) (Morey, 1991). PAI is a 344-item self-report measure of personality that is reliable in assessing borderline features (Stein et al., 2007). In this study, we included only the Borderline section (PAI-BOR, Cronbach's α = 0.91) composed of 24 items corresponding to 4 subscales: affective instability (6 items), identity problems (6 items), negative relationships (6 items), and self-harm (6 items). Participants were asked to select the response that best pertains to them. Each item was rated on a 4-point scale ranging from "Not true at all" to "Very true".

Data analysis

EEG preprocessing

EEG data were processed and analyzed in FieldTrip (v. 20220707) (Oostenveld et al., 2011) using Matlab (R2020b; The Mathworks, Natick, MA). For each participant, the data were demeaned, filtered (high-pass: 1 Hz; low-pass filter: 40 Hz; Firws filter), segmented into trials (−1.5 to 11 s) relative to the trial onset, and downsampled to 256 Hz. Bad channels and trials were detected visually and removed. Independent component analysis (ICA; runica method) was used to detect components corresponding to eye movements and eye blinks. Data segments that contained artifacts were removed and regressed out of the data. Channels that were removed prior to ICA were interpolated using the average signal of neighboring channels. Then the data were referenced to the whole-brain average.

Spectral analysis

To quantify modulation of amplitude across different frequencies, time-frequency analysis was performed across whole trials for frequencies from 0.5 to 30 Hz in steps of 0.5 Hz, using Hanning windows with a fixed window length of 2s. Time-frequency spectra were calculated for each trial, which were then averaged for each of the conditions. Given our particular interest in modulations of mu desynchronization, we extracted frequency power from a set of predefined regions of interest as a reflection of sensorimotor activity. The time range was considered up to 9.5s since the participants tapped for a short period of time on some trials. The power spectra of the four conditions were compared in the 9-13 Hz frequency range using a series of cluster permutation t-tests, with 10000 random permutations. The power in the different conditions as a grand mean across subjects over electrodes of interest (C4, C3, Cz, C5) is shown in Figure 2.

BPD traits and EEG activity

According to previous studies (Muthukumaraswamy et al., 2004; Oberman et al., 2005; Pineda, 2005; Hari et al., 1998, 2006; Pfurtscheller & Da Silva, 1999), the analyses were performed separately relatively to the selected frequencies. First, we analyzed the overall mean of the power at the alpha range and then at 10Hz when the suppression has been found and explored (i.e., Pfurtscheller & Da Silva, 1999). The mean of the power at 9-13 Hz and at 10 Hz was compared between conditions using Bonferroni-corrected paired t-tests. Then, to test whether the mu rhythm (9-13Hz; 10 Hz) was modulated by the VP adaptivity in the interactive conditions or during the individual conditions and by BPD traits (PAI-BOR), we used linear mixed models (LMM). Specifically, we measured the main effect of the conditions and BPD traits (Table 1 and 2, model 1) – treated as fixed effects – as well as their interaction (Table 1 and 2, model 2) on the mean of the power of the central electrodes (C3, C5, Cz, C4) at the selected frequencies included as the dependent variable. Observations were clustered among participants, and intercept was tested as random effects.

Analyses were performed with R-software (R Core Team, 2020), and mixed models were performed with the lme4 package (Bates et al., 2015) using the lmerTest package to compute standard errors and *p* values. The results of the interaction were visually presented using library effects (J. Fox, 2003; Ram et al., 2018). Posthoc multiple comparisons were performed with the multcomp package (Hothorn et al., 2016).

Subjective measures

LMMs were performed to test the main effect of VP adaptivity and BPD traits and their interaction on the perception of synchrony and cooperation. We used the VP adaptivity (i.e., α levels) and BPD traits (PAI-BOR) and the interaction as fixed effects while the intercept was included as a random effect, and the observations were clustered among participants.

Results

EEG results

The power during tapping (6 to 9.5s – we had to exclude 1.5s since participants finished tapping before the established time) was computed against absolute baseline (-1.5 to 0s) over the left, right, and central electrodes (C3, C5, Cz, C4) in the interactive and individual conditions. This shows that the sensorimotor mu suppression began around 6s when the tapping started, and it was also shown in the individual condition when the participants heard their self-generated taps. This result indicates that mu suppression emerges as a distinctive reflection of sensorimotor activity during action-perception processing and movements when a stimulus has been presented, regardless of whom the participants believed it belonged to. The topography of the power in interactive conditions with a moderate adaptive partner and during individual conditions is presented in Figures 3 (a) and (b). The cluster permutation test revealed no significant clusters during tapping over sensorimotor areas.

Mu rhythm and BPD traits

The analysis of mixed models with the conditions (interactive and individual) and BPD traits as fixed effects on the mean of power at 9-13Hz oscillations treated as dependent variables are presented in Table 2 and shown in Figure 4 (a). The results revealed no significant main effects of conditions or BPD traits. However, the main effect of BPD traits has been found to be toward the statistical significance ($p = .064$). No significant interaction between the BPD traits and the conditions was found. The multiple comparisons revealed no significant contrasts between the conditions.

The analysis of mixed models with the conditions (interactive and individual) and BPD traits as fixed effects on the mean of power at 10Hz oscillations treated as dependent variables are presented in Table 1 and shown in Figure 4 (b). The results suggest that the global score of BPD traits had a central role in modulating neural activity during the interaction regardless of how the VP adapted and the conditions (interactive or individual). Specifically, Figure 4 (b) shows that at increasing the levels of BPD traits the power at 10 Hz increased, suggesting a reduced mu suppression in such a scenario. No significant main effect of conditions or interaction between the conditions and BPD traits was found. The multiple comparisons revealed no significant contrasts between the conditions.

Subjective measures and BPD traits

The model with the perception of synchrony as a dependent variable showed a main effect of VP adaptivity on the perception of synchrony (F (2, 98) = 76.89, $p < .001$). No main effect of BPD traits (F (1, 48) = 1.08, $p = 0.30$) and interaction (F (2, 96) = 1.84, $p = 0.16$) were found. Concerning the perception of cooperation, results revealed a main effect of VP adaptivity (F (2, 98) = 33.98, $p <$ .001) and BPD traits (F (1, 48) = 4.13, $p < .05$). No interaction was significant (F (2, 96) = 1.47, p = 0.23).

Discussion

In the present study, we investigated the neural mechanisms underlying interpersonal coordination during an interaction with a virtual partner in different scenarios of adaptivity and individual conditions. Specifically, we aimed to explore the role of BPD traits in modulating mu rhythm during different conditions: interactive conditions – when participants interacted with a variable adaptive partner – or individual-self conditions with no interactive partner.

Overall, we found a suppression of mu rhythm (9-13 Hz) ipsilateral to the participants' movements and over sensorimotor areas in line with previous literature (i.e., Hari, 2006; Muthukumaraswamy & Johnson, 2004; Pineda & Hecht, 2009). Specifically, such activity is associated with the action-perception loop that is known to occur when engaging in motor action execution, observation, and imagining others' actions (Hari, 2006; Hari & Kujala, 2009). Notably, the suppression has been found to emerge also during the individual condition, so when the participants heard just the self-generated taps. This might indicate that participants could represent and imagine the actions during the task regardless of whom they thought the sound was produced and related to. Moreover, this finding could be an index of participants' involvement and readiness to engage by providing more attention allocated to the action-perception coupling aspects (Koban et al., 2019; Vesper et al., 2017).

In relation to the BPD traits and partially in line with our hypothesis, we found a significant role of BPD traits in the modulation of the mu rhythm's component at 10 Hz. Notably, we found that individuals with higher levels of BPD traits showed higher reduced mu suppression during the interactive and individual conditions. Since mu suppression has been considered an index of others' action representation and the disinhibition of the sensorimotor areas when these become "active" (Hari, 2006; Muthukumaraswamy et al., 2004; Pineda, 2005), we could speculate that individuals with higher BPD traits tended to interact while staying in an inflexible "resting state" maybe for being less attentive and involved in the task. Moreover, such reduced suppression was also found during individual conditions, and that might be associated with the impaired process of distinguishing between self and others and its integration as a distinctive pathological feature of individuals with high BPD traits (Beeney et al., 2016; Bender & Skodol, 2007; De Meulemeester et al., 2021). Specifically, such self and other disturbances might be rooted in a dysfunctional development mental representations during attachment relationships (Bender & Skodol, 2007; Fonagy et al., 2003; Gunderson, 2007).

In line with Kernberg's perspective, the experience of a dysfunctional motivational system might lead to developing a distorted view of self and others, which hamper the relational process and the integration of self and others' representation (Kernberg & Caligor, 2005; Yeomans et al., 2017). Such psychopathological features have an impact on how those individuals represent their own and others' mental and affective states, resulting in reduced mentalization (Fonagy et al., 2019; Fonagy & Bateman, 2008) and negative intentions and affect related to others, which might be a projection of the individual intolerable affects (Caligor et al., 2023; Kernberg & Caligor, 2005).

Relatively to the subjective ratings of the interaction, we found a main effect of VP adaptivity on the perception of synchrony and cooperation. Specifically, we found that at increasing the level of VP adaptivity, the perception of synchrony and the perception of cooperation decreased. This is in line with previous studies (Fairhurst et al., 2013; Mills et al., 2019; Gregorini et al., under review; Chapter 1) and sustains the idea that even when the VP adaptivity increased, participants seem to perceive the task as more 'difficult' resulting in a less perception of synchrony. In this sense, an extreme level of adaptivity could be perceived as 'too overwhelmed' and hamper the relational experience. However, we found a significant main effect of BPD traits on the perception of cooperation. Unexpectedly, we found that participants with high BPD traits, compared to those with lower BPD traits, perceived more cooperation regardless of the level of VP adaptivity. On the one hand, we speculate that those individuals might have perceived more cooperation along with an increased responsive partner as reactivation of an insecure-resistant or disorganized attachment relationship (Agrawal et al., 2004; Lyons-Ruth et al., 1999) and resemble a sense of *holding* that might have produced a higher sense of togetherness even though sustained by an altered representation of self and other embedded in the approach-avoidance behavior (Gregorini et al., under review; Chapter 1). However, from Kernberg's perspective, that might result from an idealization of the other while perceiving an "optimal" level of adaptivity as close to a state of "perfection." On the other hand, such feelings might result from a hypermentalization (Sharp, 2014) and, in turn, an "over attribution" to others' intentions and emotions. Notably, this impairment emerged in association when the VP was overly adaptive, which might resemble a feeling of overinclusion, and a 'hyper follower' VP might resemble a highly intrusive partner as a reactivation of early interactions (Isabella & Belsky, 1991; Jaffe et al., 2001).

Taken together, those findings suggest that the central suppression of mu rhythm might not be affected by the belief about the partner or how the VP adapts. Consistent with previous studies, the mu suppression seems to be an index of motor activity (Gastaut, 1952; Pineda, 2005) and enhancement of neural activity (Perry et al., 2011). Moreover, this neural component has been associated with the ability to represent and imagine other people's movements (even without seeing them) during social interaction as a sign of a neural state of "activity," which might lead to being more involved in the interaction. Speculatively, we could suggest that mu rhythm reflects the activation of the action-perception loop even in interactive or individual conditions (Hari, 2006; Hari & Kujala, 2009). According to a clinical perspective, such neural activity might be associated with impairments in the interpersonal domain of individuals with high BPD traits rooted in maladaptive interpersonal dispositions as well as in social cognitive impairments and polarized self and other representations (Caligor et al., 2023; Kernberg & Caligor, 2005) that might interfere with how others' actions are processes. In this sense, the quality of early interaction and, in turn, the disturbances in the formation of the representation of self and other, as well as the self in relation to the other, might potentially affect the neural representation, distinction, and then integration of the self and other's action.

However, those findings need to be considered in the context of their limitations. First, we used a small so probably we did not capture enough statistical differences concerning BPD traits with the overall assessment of mu rhythm 9-13Hz. Second, we used a nonclinical sample, so the generalizability of the results is uncertain, and future studies are encouraged in this direction. Third, we used a human-computer interaction that might be lacking in ecological validity. Fourth, the movements during the task could affect EEG measurements.

In conclusion, our results support the view that people with high dysfunctional personality dimensions could benefit from interventions (i.e., Yeomans et al., 2015; Fonagy & Bateman, 2008) addressing the distorted mental representation of self and others to improve their interpersonal functioning. Further research is encouraged to investigate which mechanisms underlie mu suppression in clinical populations.

Table 1. Results of BPD traits and mu rhythm (component at 10Hz)

	Mu 10Hz						**Mu 10Hz**					
	Model 1						**Model 2**					
Fixed effects	*b*	*SE*	*CI*	*t*	*p*	*df*	*b*	*SE*	*CI*	*t*	*p*	*df*
(Intercept)	-0.29	0.15	-0.59 – 0.00	-1.99	0.052	48.87	-0.38	0.16	-0.69 – -0.06	-2.37	0.021	64.63
VP adaptivity α = 0.5	0.01	0.02	-0.03 – 0.06	0.45	0.653	147.00	0.04	0.10	-0.15 – 0.23	0.40	0.692	144.00
VP adaptivity α = 1	-0.01	0.02	-0.05 – 0.04	-0.36	0.716	147.00	0.11	0.10	-0.08 – 0.30	1.14	0.257	144.00
Self	-0.02	0.02	-0.06 – 0.03	-0.69	0.492	147.00	0.17	0.10	-0.02 – 0.36	1.73	0.085	144.00
BPD traits	0.16	0.07	0.03 – 0.30	2.50	0.016	48.00	0.20	0.07	0.06 – 0.34	2.86	0.006	64.63
VP adaptivity α = 0.5 * BPD traits							-0.01	0.04	-0.10 – 0.07	-0.30	0.765	144.00
VP adaptivity α = 1 * BPD traits							-0.05	0.04	-0.14 – 0.03	-1.26	0.210	144.00
Self * BPD traits							-0.08	0.04	-0.17 – 0.00	-1.95	0.064	144.00
Random Effects												
σ^2	0.01						0.01					
τ_{00}	0.06 ID						0.06 ID					
ICC	0.81						0.81					
N	50 ID						50 ID					
Observations	200						200					
Marginal R^2 / Conditional R^2	0.098 / 0.827						0.102 / 0.830					
AIC	-119.920						-104.716					
log-Likelihood	66.960						62.358					

Note: BPD traits = overall measure of PAI-BOR; Model 1 = main effect of VP adaptivity(=interactive conditions)/Self (=individual condition) and BPD traits; Model 2 = Model 1 + interaction between VP adaptivity(=interactive conditions)/Self (=individual condition) and BPD traits.

Table 2. Results of BPD traits and mu rhythm (9-13 Hz)

	Mu 9-13Hz						Mu 9-13Hz					
	Model 1						Model 2					
Fixed effects	*b*	*SE*	*CI*	*t*	*p*	*df*	*b*	*SE*	*CI*	*t*	*p*	*df*
(Intercept)	-0.12	0.07	-0.25 – 0.02	-1.67	0.100	48.93	-0.12	0.07	-0.27 – 0.02	-1.68	0.098	66.18
VP adaptivity α = 0.5	-0.00	0.01	-0.02 – 0.02	-0.28	0.777	147.00	0.01	0.05	-0.09 – 0.10	0.12	0.908	144.00
VP adaptivity α = 1	-0.02	0.01	-0.04 – 0.00	-1.70	0.091	147.00	-0.03	0.05	-0.13 – 0.06	-0.71	0.479	144.00
Self	-0.01	0.01	-0.03 – 0.01	-1.08	0.283	147.00	0.03	0.05	-0.06 – 0.13	0.69	0.490	144.00
BPD traits	0.06	0.03	-0.00 – 0.12	1.90	0.064	48.00	0.06	0.03	-0.00 – 0.13	1.88	0.064	66.18
VP adaptivity α = 0.5 * BPD traits							-0.00	0.02	-0.05 – 0.04	-0.19	0.852	144.00
VP adaptivity α = 1 * BPD traits							0.01	0.02	-0.04 – 0.05	0.32	0.746	144.00
Self * BPD traits							-0.02	0.02	-0.06 – 0.02	-0.97	0.334	144.00
Random Effects												
σ^2	0.00						0.00					
τ_{00}	0.01 ID						0.01 ID					
ICC	0.80						0.80					
N	50 ID						50 ID					
Observations	200						200					
Marginal R^2 / Conditional R^2	0.061 / 0.810						0.063 / 0.809					
AIC	-408.402						-385.901					
log-Likelihood	211.201						202.951					

Note: BPD traits = overall measure of PAI-BOR; Model 1 = main effect of VP adaptivity (=interactive conditions)/Self (=individual condition) and BPD traits; Model 2 = Model 1 + interaction between VP adaptivity (=interactive conditions)/Self (=individual condition) and BPD traits.

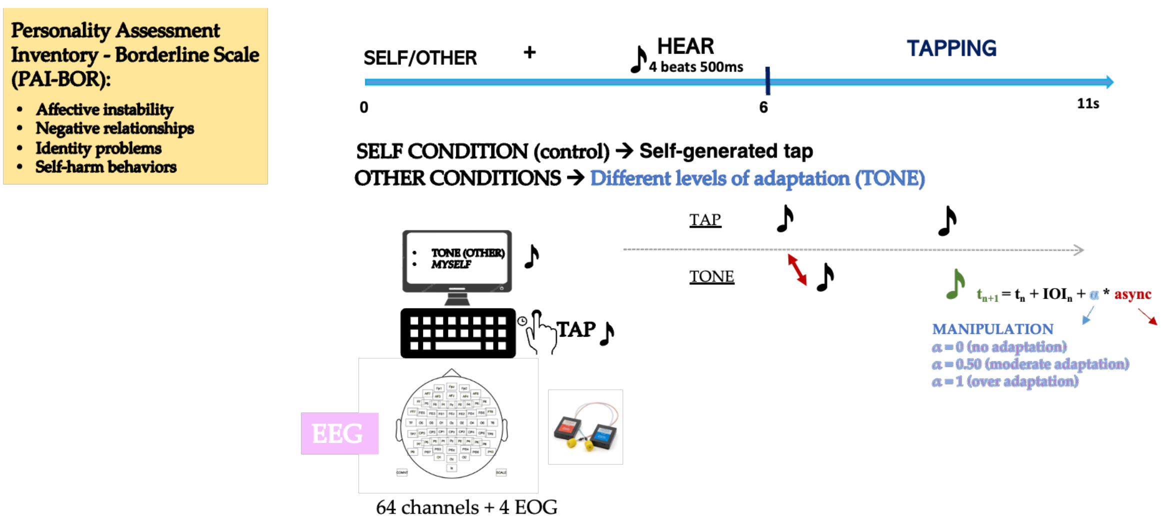


Figure 1. Experimental paradigm. Participants filled out a personality self-report then executed a finger tapping whereby they were asked to synchronize their taps with the sound that they heard. During the task EEG activity was recorded. In the interactive conditions called 'other' the sound was produced by the virtual partner and manipulated in time while during 'self' the sound was the tap of the participant. After the 'other' conditions participants were asked to evaluate perception of synchrony and cooperation.

Figure 2. The power in the interactive and individual conditions a grand mean across subjects over electrodes of interest (C3, C4, C5, Cz)

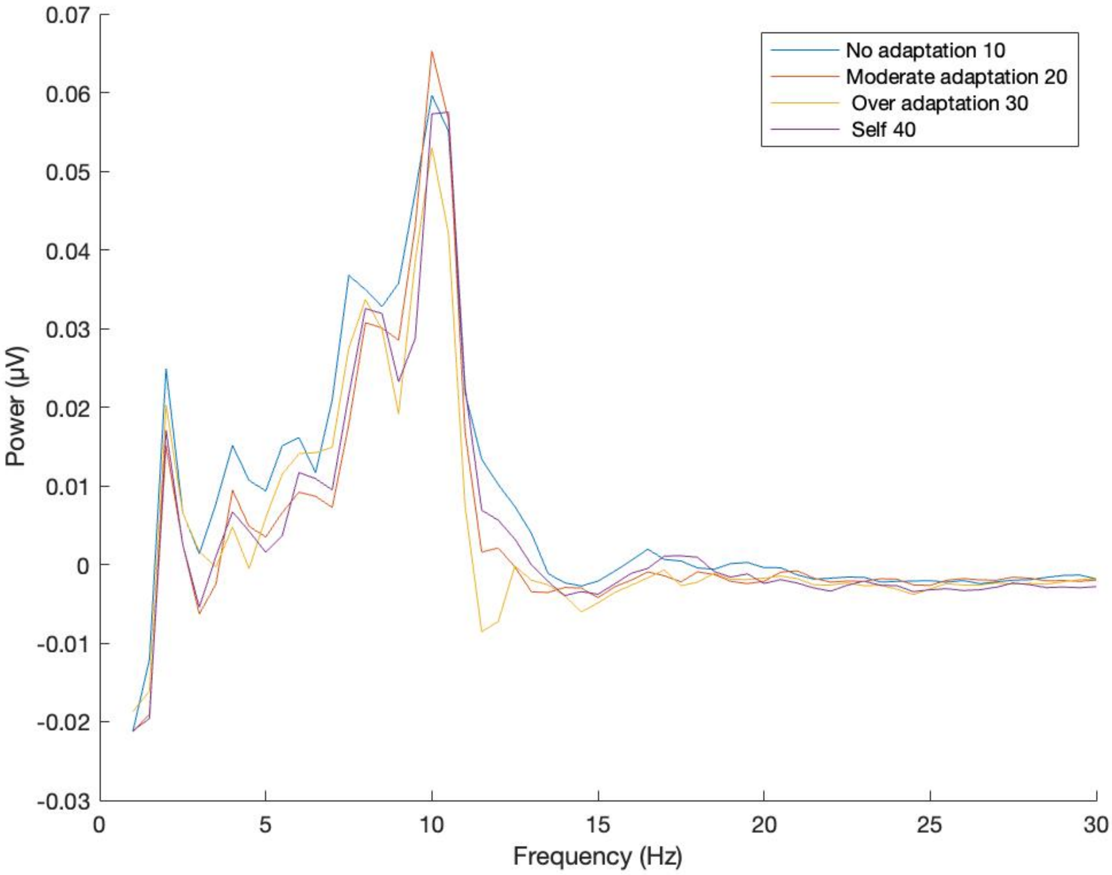


Figure 3(a). Topography during tapping at 9-13 Hz during interactive condition 'OTHER' with moderate VP adaptation

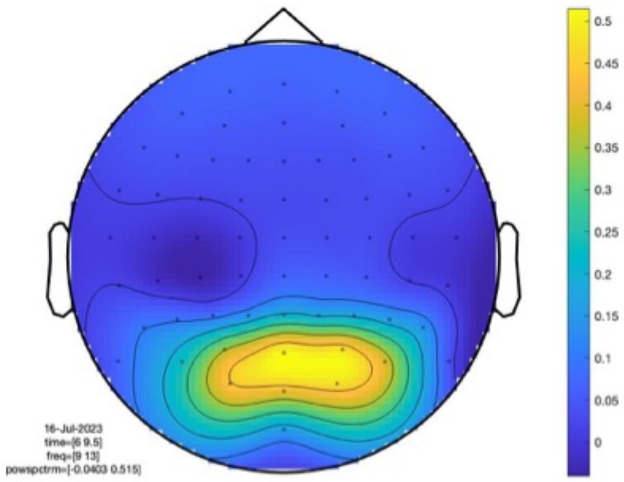


Figure 3(b). Topography during tapping at 9-13 Hz during individual condition 'SELF'

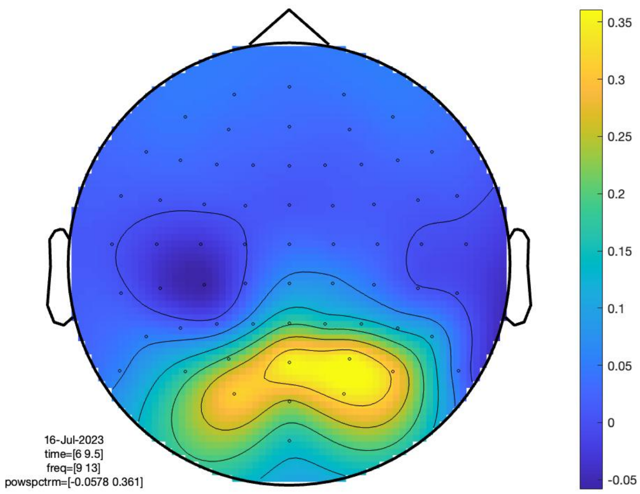


Figure 4 (a). Main effect of PAI-BOR on mu 9-13Hz

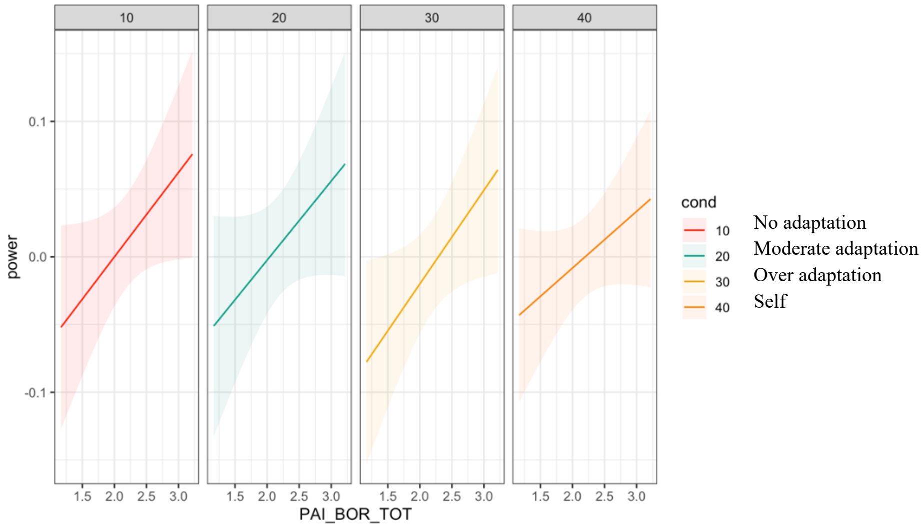
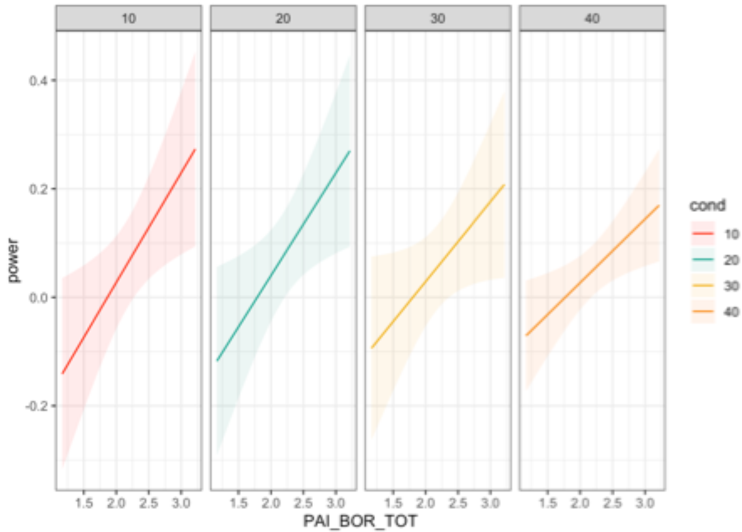


Figure 4 (b). Main effect of PAI-BOR on mu rhythm 10Hz



CHAPTER 3

Syncing trustworthiness: bidirectional effects of synchrony and trustworthiness and their associations with borderline personality traits *(in preparation)*

Gregorini, C., De Carli, P., Brambilla, M. & Preti, E.

ABSTRACT

Borderline personality disorder (BPD) has been associated with distorted perceptions of social cues and trustworthiness impairments. Although previous studies showed that synchrony was associated with positive interpersonal features, what remains unclear is whether trustworthiness and synchrony are bidirectionally associated and the potential role of BPD traits in these associations. To explore those features, we propose three studies involving participants in a finger-tapping task. In Study 1 (N = 124), we tested whether the partner's faces (manipulation) impacts synchrony; in Study 2 (N = 106), we tested whether the partner's personal descriptions (manipulation) impacts synchrony; and in Study 3 (N = 108), whether synchrony impacted trust appraisal while manipulating the temporal adaptivity of the partner. After assessing BPD traits through self-report, participants executed a finger-tapping task while asked to evaluate subjective measures after a series of trials. Studies 1 and 2 showed that trustworthiness impacts the perception of synchrony. Moreover, the partner's identity affects asynchrony in both studies but not variability. In Study 3, the perception of synchrony significantly impacted trust appraisal: trust appraisal increased when the partner was non-adaptive, at increasing the perception of synchrony and decreased when the interpersonal variability increased. However, no effect of BPD traits was found in these associations, but higher BPD traits were significantly associated with higher aggressive behaviors and negative affect. In conclusion, these findings suggest a bidirectional effect of trustworthiness and synchrony that might be relevant for extending existing findings in social cognition research but also denoting the potential role of synchrony in the therapeutic setting.

Introduction

Borderline Personality Disorder (BPD) is a complex psychiatric condition characterized by emotional dysregulation, unstable relationships, identity disturbances, impulsivity, and self-harm behaviors (Lieb et al., 2004; Skodol et al., 2002). BPD has been associated with deficits in social cognition processes (Herpertz & Bertsch, 2014; Poggi et al., 2019; Roepke et al., 2013), interpersonal disturbances (Gunderson, 2007), and higher emotional dysregulation (Linehan, 1993).

Heightened sensitivity to interpersonal stimuli and an intense negative reactivity (i.e., anger and aggression) (Arntz et al., 2000; Barnow, Stopsack, et al., 2009) are related to BPD. Moreover, individuals with BPD features show an untrustworthiness bias that coincides with the attitude that *"whether others will reject, be dishonest with, negatively judge, or otherwise emotionally hurt"* (Fertuck et al., 2013). Such impairment seems to hamper cooperation and social interaction (Seres et al., 2009). Empirical findings (Jeung et al., 2016; King-Casas et al., 2008; Lazarus et al., 2018; Unoka et al., 2009) showed that during interactive contexts individuals with BPD tend to show an inability to modulate their expectations and a reduced ability to respond cooperatively to social signals of trustworthiness. Moreover, during a *Cyberball* task individuals with BPD reported less social connection during "overinclusion" conditions than the controls and lower negative affect (De Panfilis et al., 2015). Those findings suggest the need to investigate the mechanisms that might be implicated in untrustworthiness bias, and that might be rooted in psychological structures that sustain cognitive distortions (the other is "bad") (Clarkin et al., 2007).

Moreover, individuals with BPD might show a reduced epistemic trust as "*the one's ability to trust others and rely on the information they convey as being relevant and generalizable"* (Fonagy et al., 2019; Luyten et al., 2020). The traumatic early experiences in the attachment environment as precursors of BPD (Fonagy & Luyten, 2009; Gunderson & Lyons-Ruth, 2008; Levy et al., 2011) might have hampered an adequate experience of ostensive communicative cues and the self-development (Csibra, 2010; Csibra & Gergely, 2009; Egyed et al., 2013). Further, the *"we mode"* would be disturbed (Fisher et al., 2023; Milesi et al., 2023) damaging the interaction coupling.

However, the ability to reach a "we-mode" (Jenkins et al., 2021; Sebanz et al., 2006) is central for social interaction and also promotes interpersonal synchrony (Heggli et al., 2019; Keller et al., 2016). In this interactive process, cooperation and trust have been considered as central dispositions that might sustain coordination and mutual adaptation as a functional synchronization strategy (Dumas & Fairhurst, 2021; Konvalinka et al., 2023).

Furthermore, synchrony seems to enhance social processes such as feelings of connectedness and interpersonal rapport (Chartrand & Bargh, 1999; Hove & Risen, 2009; Rennung & Göritz, 2016; Wiltermuth & Heath, 2009) promoting the co-regulation and the coupling within social interaction. For instance, Launay and colleagues showed that synchronization elicits a feeling of trust even in interaction with a virtual partner and with no visual contact (Launay et al., 2013). Additionally, a recent meta-analysis by Mogan and colleagues (Mogan et al., 2017) found a positive relationship between synchronous movements and prosocial behaviors, perceived social bonding, social cognition, and positive affect. Recently, we found (Gregorini et al., under review; Chapter 1) that individuals with high BPD features showed a lower perception of synchrony and a higher negative affect during synchronized interactions. Specifically, we found that even when the partner was moderately adaptive in facilitating interpersonal synchrony individuals with high BPD traits might have perceived rejection, mistrust, and less prosocial behaviors reporting lower perception of synchrony and higher negative affect compared to individuals with low BPD traits. However, BPD has been well investigated in relation to the difficulties in processing social information, emotions, and social stimuli (Domes et al., 2009; Hepp et al., 2017). For instance, in relation to trait appraisal, individuals with high BPD traits rated neutral faces as more untrustworthy (Fertuck et al., 2013; Miano et al., 2013; Richetin et al., 2018). Moreover, in a clinical sample, BPD patients evaluated trustworthy faces as less trustworthy compared to the controls (Fertuck et al., 2019). Moreover, individuals with BPD are more prone than controls to attribute higher negative emotions to neutral and ambiguous stimuli (Arntz & Veen, 2001; Domes et al., 2008; Meyer et al., 2004) as well as when in more structured contexts (Minzenberg et al., 2006). Furthermore, the higher sensitivity to social rejection (Downey & Feldman, 1996) rooted in insecure attachment (Agrawal et al., 2004; Gunderson & Lyons-Ruth, 2008) seems to mediate the relationship between untrustworthy appraisal and BPD features (Miano et al., 2013). Then, the higher negative affect as a component of emotional dysregulation (Linehan, 1993) seems to be a direct consequence of emotional sensitivity in BPD (Carpenter & Trull, 2013). Specifically, studies showed that individuals with BPD features showed higher negative affect (hostility and anger) (Berenson et al., 2011; Dixon-Gordon et al., 2011, 2015; Miskewicz et al., 2015; Staebler et al., 2011) after rejection (Beeney, 2014; Chapman et al., 2014; Renneberg et al., 2012).

In line with this, individuals with BPD tend to respond with aggression to perceived interpersonal rejection, ostracism, or criticism (Ayduk et al., 1999). Specifically, negative interpersonal events (rejection) mediated the association between BPD and aggression (Herr et al., 2013). Consistent with that, Scott and colleagues found that anger reactivity to perceived rejection is a pathway by which BPD symptoms increase the risk for aggression (Scott et al., 2017). However, a limited number of research investigating the role of trustworthiness during synchronized interaction and the psychopathological implications.

In the current study, we propose three studies to explore the role of trustworthiness during a synchronized interaction and the role of BPD traits. Specifically, in all the studies we used the experimental task of finger-tapping presented in Chapter 1 to measure interpersonal synchrony and obtain a measure of the perception of synchrony. In studies 1 and 2, we aimed to test whether trustworthiness impacts the perception of synchrony, interpersonal synchrony, aggressive behavior, and the negative affect while the virtual partner (VP) is moderately adaptive ($\alpha = 0.5$) to the participants' taps. We expected a main effect of trustworthiness on the perception of synchrony, interpersonal synchrony, aggressive behavior, and negative affect. Consistent with a theoretical perspective (Fonagy et al., 2019; Kernberg & Caligor, 2005) and previous findings (i.e., Ayduk et al., 2008; Fertuck et al., 2013, 2019), we expected a main effect of BPD traits resulting in low perception of synchrony, interpersonal synchrony and higher aggressive behaviors, and negative affect. As exploratory hypotheses, we also tested the moderation effect of BPD traits in interaction with the trustworthiness's manipulation.

In study 3, we aimed to explore whether synchrony (perception of synchrony and interpersonal synchrony) and the modulation of the VP adaptivity might impact the trust appraisal while interacting with a VP with a neutral facial expression. Here, VP could vary, producing non-adaptive ($\alpha = 0$) or moderately adaptive sound ($\alpha = 0.5$). We expected a main effect of VP adaptivity, perception of synchrony, and interpersonal synchrony on trust appraisal. In line with the higher rejection sensitivity of individuals with BPD features (Ö. Ayduk et al., 2008; Berenson et al., 2011; Hepp et al., 2017), and the untrustworthiness bias (Miano et al., 2013; Richetin et al., 2018) in processing neutral stimuli, we expected that individuals with high BPD traits would perceive low trust and would report high aggressive behaviors and negative affect regardless of VP adaptivity.

Study 1

Study 1 tested the hypothesis that identity manipulation through faces (varying in trust/untrust and competence/incompetence) influences synchrony (interpersonal synchrony and perception of synchrony), aggressive behaviors, and negative affect. We supposed that BPD traits play a role in this association. After assessing BPD traits through self-report, participants were asked to execute a synchronized finger-tapping task, interacting with the partner presented during tapping. We used the competence and incompetence dimensions as control conditions for the valence effect. The task comprised 16 trials divided into 4 blocks; after each interaction block, participants rated subjective measures.

Method and Materials

Participants

We conducted a priori power analysis with GPower (latest ver. 3.1.9.7; Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany; http://www.gpower.hhu.de/) that required a minimum sample size of N = 101 for a one-tail test with power 0.80, alpha (α) 0.05, and effect size (d) 0.25.

After the approval by The Institutional Review Board of the University of Milan Bicocca, participants were recruited with flyers and online advertisements. N = 124 (M*age* = 24.5; SD*age* = 6.80). Italian participants volunteered to participate in the study.

Stimuli

We employed 16 computer-generated avatars' male faces (4 trustworthy, 4 untrustworthy, 4 competent, and 4 incompetent) selected from the stimuli developed and psychometrically validated by Todorov and colleagues (Todorov et al., 2013). Faces were displayed for a maximum of 12 sec on a black screen of 500x500 pixels.

Personality Assessment

To assess the BPD traits, participants were asked to fill out the Personality Assessment Inventory-Borderline Scale (PAI-BOR) (Morey, 1991) via Qualtrics. PAI is a 344-item self-report measure of personality that is reliable in assessing borderline features (Stein et al., 2007). In this study, we included only the Borderline section (PAI-BOR) composed of 24 items corresponding to 4 subscales: affective instability (BOR- A), identity problems (BOR-I), negative relationships (BOR-N), and self-harm behaviors (BOR-S). Participants were asked to choose the response that best pertains to them. Each item was rated on a 4-point scale (1 = “Not true at all”; 4 = “Very true”). For the purposes of this study, we focused on the global scale (PAI-BOR, Cronbach's $\alpha = 0.89$).

Subjective measures

At the end of each block of interaction, participants were asked to rate the interaction with each partner on perceived synchrony (“How much did you feel in synchrony with the partner?”) using a 6-point Likert scale (0 = “Not at all”; 5 = “Completely”); trust appraisal (“How much trustworthy was your partner?”) using a 7-point Likert sale (0 = “Not at all”; 7 = “Completely”); positive (5 items) and negative (5 items) affect using the I-PANAS-SF (Thompson, 2007) on a 5-point Likert scale (1 = “never”; 5 = “always”); prosocial (5 items) and aggressive (5 items) behavioral tendencies (Riva et al., 2015) using a 7-point Likert scale (1 = “Not at all attempted”; 7 = “Very attempted”). For the purposes of this study, we focused on the score of negative emotions and aggressive behavioral tendencies.

Data analysis

Tapping measures

According to the previous procedure (Gregorini et al., *under review; Chapter 1*), the tapping task data were initially preprocessed to keep the measures of interpersonal synchrony (the difference between the tap and the tone in each trial) within +/-3 Standard Deviation (SD) from the average scores of each participant. Two types of analyses were computed: absolute mean of asynchrony and variability of asynchrony.

The absolute mean of asynchrony was computed as the difference between the taps and the tones and averaged across conditions. This index was considered a measure of the accuracy of the performance, and the magnitude of the asynchrony was independent of the earliness (negative asynchrony) or lateness (positive asynchrony) of the dynamics. Therefore, higher values indicated lower synchrony (i.e., more asynchrony), while lower scores indicated higher synchrony.

The variability of the performance was computed through the SD of the asynchrony as an index of the variability of the performance. The variability index was an inverse measure of precision indicating how unstable the tap timing was around the pacing events, where higher values indicate more instability as well as variability in tapping.

Results

A linear mixed model was used to test the within-subjects fixed effects of different conditions (VP faces) and BPD traits (PAI-BOR total score) on dependent variables: trust appraisal, synchrony (behavioral measures and perception of synchrony), aggressive behavior, and negative affect. The random term was the intercept, while observations were clustered among participants. We tested the main effect of conditions and BPD traits on the dependent variables and the moderation effect of BPD traits in interaction with the conditions. Pairwise comparisons (Tukey's HSD, honestly significant difference) were performed to test the differences between the means of the conditions. The manipulation check confirmed our hypotheses and revealed a significant main effect of the manipulation on the trust appraisal (F (3,363) = 20.71, p < .001).

As expected, results showed a significant main effect of conditions on the perception of synchrony (F (3,363) = 9.02, p < .001). However, contrary to our hypotheses, no main effect of BPD traits (F (1,120) = 0.19, p = 0.65) or interaction (F (3,360) = 0.29, p = 0.82) was found. Pairwise comparisons revealed significant differences between competence and incompetence (b = 0.48, SE = 0.01, t (363) = 3.78, p = 0.001, 95% CI [3.07, 3.57]) and competence and untrust (b = 0.54, SE = 0.01, t (363) = 4.23, p = 0.002, 95% CI [3.07, 3.57]). Then we found significant differences between incompetence and trust (b = -0.38, SE = 0.01, t (363) = -3.01, p = 0.014, 95% CI [2.59, 3.09]) as well as trust and untrust (b = 0.44, SE = 0.01, t (363) = 3.46, p = 0.003, 95% CI [2.53, 3.03]). This suggests a main valence effect indicating that participants perceived more synchrony when the facial expression is positive (trust and competence) vs. negative (untrust and incompetence).

In relation to the behavioral measures of synchrony, we found a main effect of conditions on the asynchrony (F (3,359.53) = 3.38, p = .018) but no main effect of BPD (F (1, 120.13) = 1.03, p = 0.31) or moderation (F (3, 356.44) = 1.28, p = 0.28). Pairwise comparisons revealed no significant differences between the conditions. Regarding the variability of the asynchrony, we found a main effect of conditions (F (3,358.88) = 4.36, p < .01) but no main effect of BPD traits (F (1,120.01) = 0.14, p = 0.70) and interaction were found (F (3,356.44) = 1.28, p = 0.28). Pairwise comparisons revealed differences between competence and incompetence (b = 0.001, SE = 0.0004, t (359) = 2.52, p = 0.05, 95% CI [0.02 0.02]); competence and untrust (b = 0.001, SE = 0.0004, t (359) = 3.51, p < .01, 95% CI [0.02 0.02]).

In relation to the aggressive behavior, as expected, we found a main effect of conditions (F (3,363) = 6.86, p < .001) and a main effect of BPD traits (F (3,363) = 6.38, p = .01). However, no interaction was found (F (3,360) = 0.49, p = 0.68). Pairwise comparisons revealed a significant difference between competence and untrust (b = -0.02, SE = 0.07, t (363) = -3.10, p = 0.01, 95% CI [1.49, 1.77]); and between trust and untrust (b = -0.31, SE = 0.07, t (363) = -4.39, p = 0.0001, 95%

CI [1.33, 1.61]). This suggests that individuals report more aggressive behavior when the facial expression is negative (untrust), but individuals with high BPD traits report more aggressive behaviors than individuals with low BPD, regardless of the conditions.

In relation to negative affect, as expected, we found a main effect of conditions (F (3,363) = 3.81, p = .01) and a main effect of BPD traits (F (1,120) = 8.85, p < .01) but no interaction was found (F (3,360) = 0.35, p = 0.78). Pairwise comparisons revealed significant differences between trust and untrust (b = -0.19, SE = 0.05, t (363) = -3.34, p = 0.005, 95% CI [1.41, 1.68]). The negative affect increased when the facial expression of the partner was untrustworthy, but individuals with high BPD traits showed an increase in negative affect compared to those with low BPD traits regardless of the conditions. Results are presented in Figure 1.

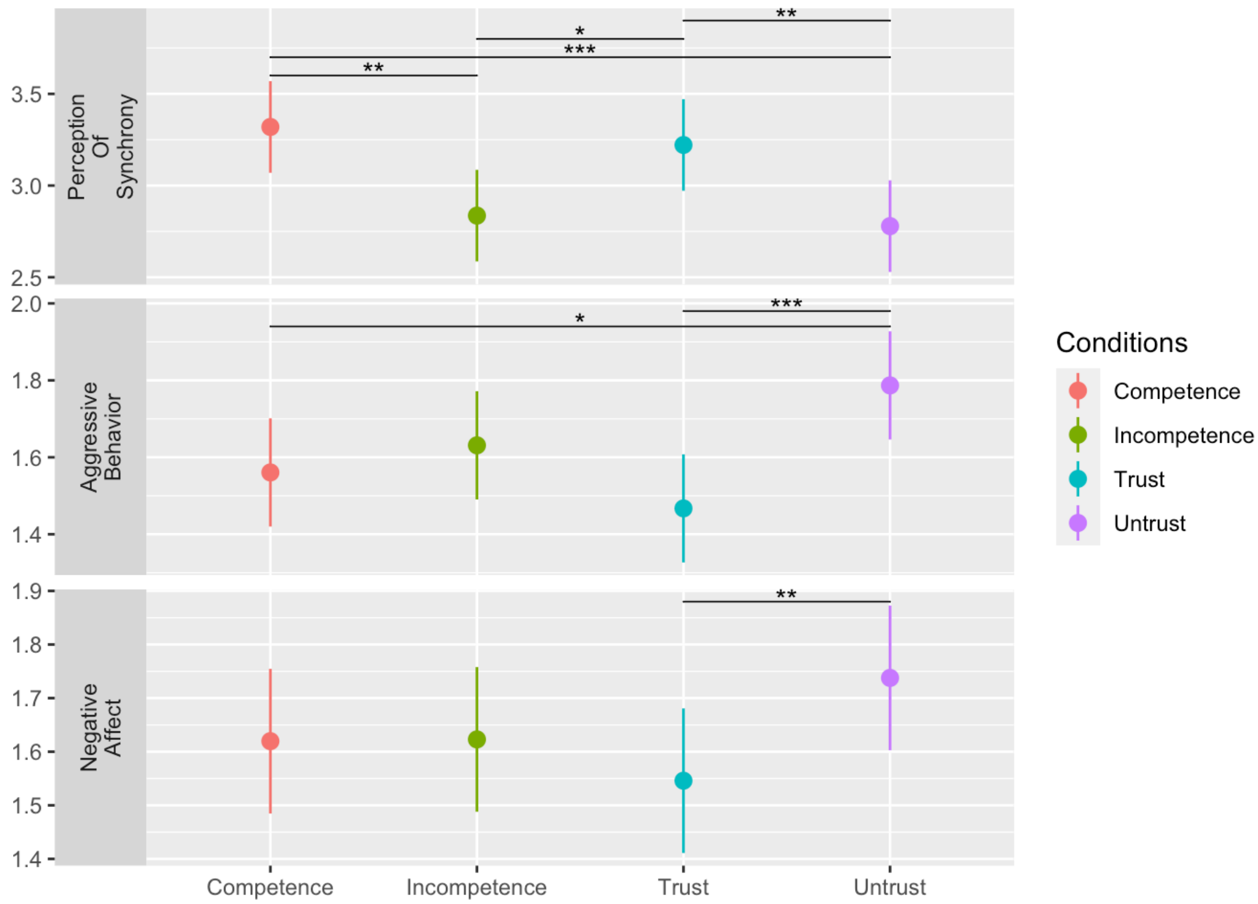


Figure 1. Differences in average between conditions on the dependent variables: perception of synchrony, aggressive behavior, negative affect. Error-bars represent standard errors of the mean. * = p < .05; ** = p < .01; *** = p < .001

Study 2

Study 2 tested the hypothesis that identity manipulation through personal descriptions (varying in trust/untrust and competence/incompetence) influences synchrony (interpersonal synchrony and perception of synchrony), aggressive behavior, and negative affect. We supposed that BPD traits play a role in this association. After assessing BPD traits through self-report (see study 1), participants were asked to execute a synchronized finger-tapping task, interacting with the partner presented during the tapping. We used the competence and incompetence dimensions as control conditions for the valence effect. The task comprised 16 trials divided into 4 blocks; after each interaction block, participants rated subjective measures (see Study 1). The interpersonal synchrony measures were computed following the procedure presented in the Data analysis section in Study 1.

Method and Materials

Participants

We conducted a priori power analysis with GPower (latest ver. 3.1.9.7; Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany; http://www.gpower.hhu.de/) that required a minimum sample size of N = 101 for a one-tail test with power 0.80, alpha (α) 0.05, and effect size (d) 0.25. After the approval by The Institutional Review Board University of Milan Bicocca, participants were recruited with flyers and online advertisements. N = 106 (M*age* = 24; SD*age* = 5.48) Italian participants volunteered to participate in the study.

Stimuli

We employed 24 partners' descriptions (Brambilla et al., 2019) that varied along the trustworthiness and untrustworthiness dimension and competence and incompetence dimension as control. Those descriptions were matched with 5 computer-generated avatars' male faces (neutral) selected from the stimuli developed and psychometrically validated by Todorov and colleagues (Todorov et al., 2013). Descriptions matched with the partners' faces appeared on the screen for 2 secs then, during tapping, the partner's face remained on the screen for a maximum of 12 sec on a black screen 500x500.

Results

A linear mixed model was used to test the within-subjects fixed effects of different conditions (VP personal descriptions) and BPD traits (PAI-BOR total score) on dependent variables: trust appraisal, synchrony (behavioral measures and perception of synchrony), aggressive behavior, and negative affect. The random term was the intercept while observations were clustered among participants. We tested the main effect of conditions, BPD traits, and the moderation effect of BPD traits in interaction with the conditions on the dependent variables. Pairwise comparisons (Tukey's HSD, honestly significant difference) were used to test the differences between the means of the conditions.

First, we tested the effect of conditions on the trust appraisal as a manipulation check and we found a significant main effect of conditions (F (3,319.61) = 175.07, $p < .001$).

In relation to the perception of synchrony and partially in line with our hypothesis, we found a main effect of conditions (F (3,318.91) = 54.82, $p < .001$) but no main effect of BPD traits (F (1, 109.25) = 0.005, p = 0.98) and no interaction (F (3,315.91) = 1.31, p = 0.27) was found. Pairwise comparisons showed a significant difference between competence and trust (b = -0.42, SE = 0.13, t (319) = -3.13, p = 0.01, 95% CI [2.68 3.20]) and competence and untrust (b = 1.22, SE = 0.13, t (319) = 9.12, $p < .001$, 95% CI [2.68 3.20]). Then significant differences were found between incompetence and trust (b = -0.52, SE = 0.13, t (319) = -3.90, p = 0.0007, 95% CI [1.45 1.97]) and incompetence and untrust (b = 1.12, SE = 0.13, t (319) = 8.35, $p < .001$, 95% CI [2.57 3.10]). Further, between trust and untrust (b = 1.64, SE = 0.13, t (319) = 12.25, $p < .0001$, 95% CI [3.10 3.62]). The results suggest a valence effect and that participants perceived more synchrony when the partner's descriptions were trustworthy (positive) rather than untrustworthy, competent, or incompetent.

In relation to the behavioral measures, we found a main effect of conditions on asynchrony (F (3,318.97) = 8.36, $p < .001$) but no main effect of BPD (F (1,118.68) = 0.21, p = 0.64) or interaction

(F (3,315.97) = 0.31, p = 0.81) was found. Pairwise comparisons showed a significant difference between competence and incompetence (b = 0.006, SE = 0.001, t (319) = 4.41, p = 0.0001, 95% CI [0.04 0.04]); competence and trust (b = 0.005, SE = 0.001, t (319) = 3.84, p = 0.0008, 95% CI [0.04 0.04]) and untrust (b = 0.005, SE = 0.001, t (319) = 3.92, p = 0.0006, 95% CI [0.04 0.04]).

In relation to the variability of asynchrony, no main effect of conditions (F (3,315.84) = 0.59, p = 0.61), BPD traits (F (1,111.13) = 0.41, p = 0.52), and interaction (F (3,315.84) = 0.27, p = 0.84) were found. Pairwise comparisons showed no significant differences.

In relation to the aggressive behaviors, as expected, we found a main effect of conditions (F (3,316.09) = 3.15, $p < .05$) but no main effect of BPD traits (F (1,107.06) = 1.82, p = 0.17) and no interaction (F (3,316.09) = 0.29, p = 0.82). Pairwise comparisons revealed significant differences between competence and untrust (b = -1.22, SE = 0.10, t (319) = -11.83, $p < .0001$, 95% CI [1.33 1.67]); incompetence and untrust (b = -1.32, SE = 0.10, t (319) = -12.82, $p < .0001$, 95% CI [1.23 1.56]) and trust and untrust (b = -1.36, SE = 0.10, t (319) = -13.15, $p < .0001$, 95% CI [1.19 1.53]). The results reveal that participants tended to report more aggressive behaviors in relation to untrustworthy descriptions of the partner compared to when the descriptions were trustworthy, competent, or incompetent. Unexpectedly, no main effect of BPD traits was found.

In relation to the negative affect, as hypothesized we found a main effect of conditions (F (3,319.46) = 45.27, $p < .001$) and of BPD traits (F (1, 108.95) = 13.31, $p < .001$) but no interaction (F (3,316.83) = 1.03, p = 0.37). Pairwise comparisons revealed significant differences between competence and trust (b = 0.28, SE = 0.06, t (319) = 4.44, p = .0001, 95% CI [1.52 1.76]) and competence and untrust (b = -0.45, SE = 0.06, t (319) = -7.02, $p < .0001$, 95% CI [1.52 1.76]). Then we obtained differences between incompetence and trust (b = 0.26, SE = 0.06, t (319) = 4.13, p = 0.0003, 95% CI [1.50 1.74]) and incompetence and untrust (b = -0.47, SE = 0.06, t (319) = -7.33, $p <$ .0001, 95% CI [1.50 1.74]). In addition, we found significant differences between trust and untrust (b = -0.74, SE = 0.06, t (319) = -11.46, $p < .0001$, 95% CI [1.23 1.47]). These results suggest that participants perceived higher negative affect when the descriptions of the partner were untrust than competent or incompetent. Moreover, they perceived higher negative affect in competence and incompetence conditions than trustworthiness. However, individuals with high BPD traits reported higher negative affect than individuals with low BPD traits, regardless of the conditions. Results are presented in Figure 2.

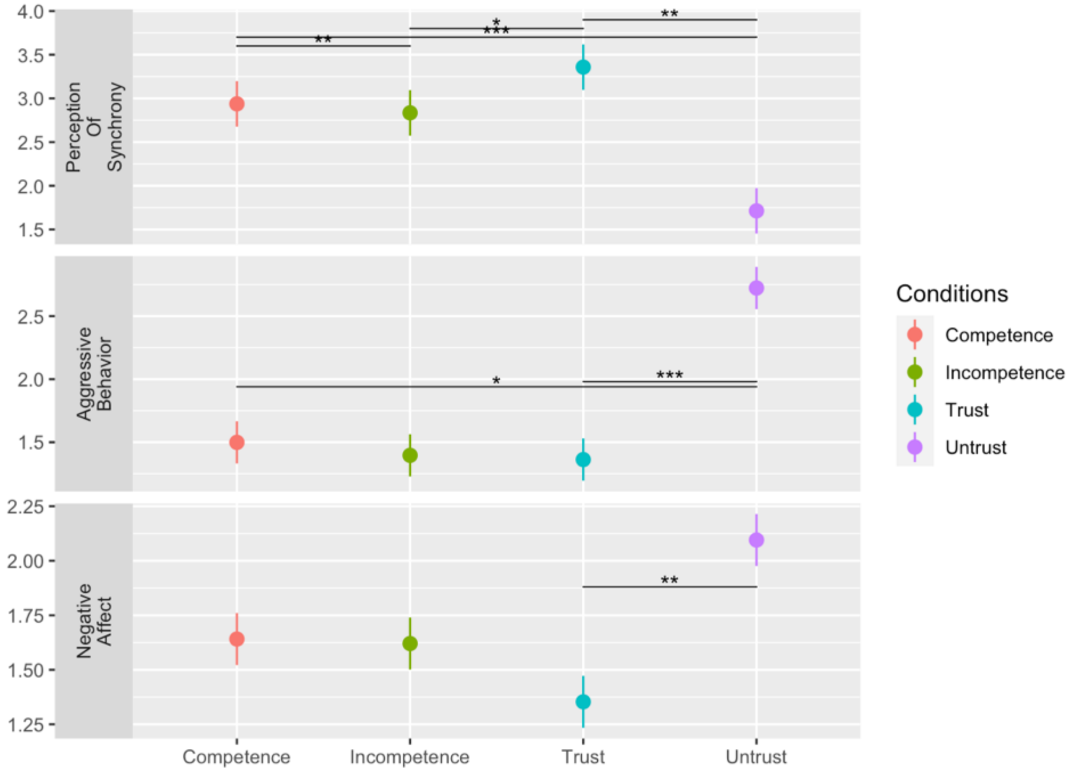


Figure 2. Differences in average between conditions on the dependent variables: perception of synchrony, aggressive behavior, negative affect. Error-bars represent standard errors of the mean. * = $p < .05$; ** = $p < .01$; *** = $p < .001$

Study 3

Study 3 tested the hypothesis that manipulating the temporal adaptation of VP (non-adaptive or moderately adaptive), interpersonal synchrony, and perception of synchrony would influence trust appraisal, aggressive behavior, and negative affect. We supposed that BPD traits play a role in this association. After assessing BPD traits through self-report (see study 1), participants were asked to execute a synchronized finger-tapping task. During the task, participants were instructed to synchronize their taps with the sound while interacting with partner displayed during the task (neutral faces). We used the competence and incompetence dimensions as control conditions for the valence effect. The task was composed of 20 trials divided into 2 blocks; after each block of interaction, participants rated subjective measures (see study 1). The interpersonal synchrony measures were computed following the procedure presented in the Data analysis section in Study 1.

Method and Materials

Participants

We conducted a priori power analysis with GPower (latest ver. 3.1.9.7; Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany; http://www.gpower.hhu.de/) that required a minimum sample size of N = 101 for a one-tail test with power 0.80, alpha (*α)* 0.05, and effect size (*d*) 0.25. After the approval by The Institutional Review Board University of Milan-Bicocca, participants were recruited with flyers and online advertisements. N = 108 (M*age* = 23.5; SD*age* = 3.56) Italian participants volunteered to participate in the study.

Stimuli

We employed 5 computer-generated avatars' male faces (neutral) selected from the stimuli developed and psychometrically validated by Todorov and colleagues (Todorov et al., 2013). Partners' faces were displayed on the screen for a maximum of 12 sec on a black screen of 500x500 pixels.

Results

A linear mixed model was used to test the within-subjects main fixed effects of different levels of VP adaptivity ($\alpha = 0$; $\alpha = 0.5$), synchrony (behavioral measures and perception of synchrony), and BPD traits on dependent variables: trust appraisal, aggressive behavior, and negative affect. The random term was the intercept while observations were clustered among participants. Pairwise comparisons (Tukey's HSD, honestly significant difference) were used to test the differences of the means between the different levels of VP adaptivity.

In relation to trust appraisal, we found a main effect of the VP adaptivity (F (1,160.75) = 5.35, $p < .05$) and a significant difference between non-adaptation ($\alpha = 0$) and moderate adaptation ($\alpha = 0.5$) ($b = 0.16$, SE = 0.07, t (163) = 2.30, $p = 0.02$, 95% CI [4.07 4.45]) of the VP. This result suggests that there is an association between how participants perceived trustworthiness and how VP adapted. Specifically, when the VP was well predictable but non-adaptive ($\alpha = 0$), participants perceived more trustworthiness than when the VP was moderately adaptive.

Then, the perception of synchrony (F (1,179.06) = 148.97, $p < .001$) had a main effect on trust appraisal: the trust appraisal increased at increasing the perception of synchrony.

Moreover, we found a main effect of the variability of the asynchronies (F (1,168.06) = 4.71, $p < .05$) on trust appraisal, revealing that at increasing the variability, the trust appraisal decreased. However, asynchrony (F (1, 205.91) = 0.28, $p = 0.59$) and BPD traits (F (1,100.56) = 0.42, $p = 0.51$) reported no significant effects.

In relation to aggressive behavior, we found a main effect of the perception of synchrony (F (1,197.65) = 18.89, $p < .001$). This suggests that individuals perceived more synchrony in association with low aggressive behaviors. Then we found a main effect of BPD traits (F (1,103.27) = 12.23, $p < .001$) suggesting that individuals with high BPD traits reported higher aggressive behaviors than individuals with low BPD traits. No main effect was found for the VP's adaptivity (F (1,165.89) = 0.37, $p = 0.53$), asynchrony (F (1, 201.68) = 0.68, $p = 0.40$), and variability (F (1,188.52) = 0.03, $p = 0.84$). Pairwise contrasts revealed no significant differences between non-adaptation ($\alpha = 0$) and moderate adaptation ($\alpha = 0.5$) ($b = 0.03$, SE = 0.05, t (166) = 0.61, $p = 0.54$, 95% CI [1.43 1.66]) of the VP.

In relation to negative affect, we found a main effect of perception of synchrony (F (1,191.75) = 46.70, $p < .001$) suggesting an association between the two variables and that at increasing the perception of synchrony the negative emotions reduced. Then we found a main effect of BPD traits (F (1,104.57) = 18.03, $p < .001$) suggesting that individuals with high BPD traits reported higher negative affect than individuals with low BPD traits. No effect of VP adaptivity (F (1,165.86) = 0.02, $p = 0.87$), asynchrony (F (1,204.69) = 0.12, $p = 0.72$), and variability (F (1,181.74) = 0.83, $p = 0.36$) was found. Pairwise contrasts revealed no significant differences between non-adaptation ($\alpha = 0$) and moderate adaptation ($\alpha = 0.5$) ($b = 0.006$, SE = 0.04, t (165) = 0.15, $p = 0.87$, 95% CI [1.49 1.69]) of the VP.

General discussion

In this study, we tested the bidirectional effect of trustworthiness and synchrony and the role of BPD traits. In studies 1 and 2, we tested whether trustworthiness influenced synchrony and the emotional components during a synchronized interaction with a VP moderately adaptive. In study 3, we tested whether synchrony affected trustworthiness and the emotional components during a synchronized interaction with a non-adaptive or moderate adaptive VP. In addition, we tested whether the levels of BPD traits could modulate those associations.

In studies 1 and 2, as we expected, trustworthiness influenced how participants perceived synchrony. Specifically, in study 1, we found that participants perceived more synchrony when the partner's identity had a positive valence (competence and trust faces) than negative (untrust and incompetence faces). Furthermore, in study 2, the perception of synchrony increased in relation to the partner's trustworthy description than in the other conditions. These results suggest that trustworthiness (regardless of the type of identity manipulation) enhances affiliation and prosocial feelings. However, contrary to our hypothesis, BPD traits did not modulate those associations. This unexpected result suggests that the emotional-driven stimuli might play a role during interaction underpinning a sense of closeness and social proximity. Furthermore, providing a new perspective, compared to previous findings (i.e., Dixon-Gordon et al., 2017; Seres et al., 2009) but also extending previous findings (Gregorini et al., under review; Chapter 1), we speculate that social interaction with a moderate adaptive partner might increase the feeling regardless of BPD levels at changing the emotional-driven stimuli.

Regarding the behavioral measures of interpersonal synchrony, as hypothesized, the results revealed an association between partner's identity manipulation and asynchrony in studies 1 and 2. Specifically, in study 1, the partner's identity (faces) influenced the asynchrony, but no differences between the conditions were found. In study 2, the asynchrony was higher in competence conditions than the other conditions. Furthermore, as hypothesized, in Study 1, the results revealed an association between the partner's identity manipulation and variability. Surprisingly, participants were more variable when the partner was positive (competence faces) than in the other conditions. However, contrary to our hypothesis, the association was not significant in Study 2, and BPD traits did not play a significant role. These results suggest a significant relationship between the partner's identity and the interpersonal synchrony. However, the tendency of the asynchrony seems to be incoherent with our expectations in relation to the valence of the conditions. Furthermore, in line with our hypotheses, aggressive behaviors were affected by the partner's identity in studies 1 and 2. Moreover, as expected, in study 1, BPD traits had a main effect on aggressive behavior, suggesting that socio-emotional processing might underpin the impaired emotional recognition in individuals with high BPD features, enhancing interpersonal antagonism (Dziobek et al., 2011; Minzenberg et al., 2006). Conversely, in study 2, BPD traits had no effect.

Moreover, in studies 1 and 2, the partner's identity significantly affected the negative affect, and BPD traits played a role in these associations. Specifically, individuals with high BPD traits showed higher negative affect than individuals with low BPD traits regardless of the manipulation. This result aligns with previous findings (i.e., Daros et al., 2014; Dyck et al., 2009) suggesting that individuals with high BPD traits tend to perceive the stimulus as negative according to cognitive distortions that might be rooted in fear of rejection and abandonment (Ö. Ayduk & Gyurak, 2008; Berenson et al., 2009; Chapman et al., 2011). However, this result extends our previous findings (Gregorini et al., under review; Chapter 1), suggesting that individuals with high BPD traits lived the interaction with higher negative affect while not modulating at changing the characteristics of the interactive partner.

In study 3, we found a main effect of the manipulation of the VP adaptivity on the trust appraisal, suggesting that trustworthiness increases in association with a non-adaptive and well-predictable partner compared to a moderate adaptive partner. Furthermore, the trust appraisal increased at increasing the perception of synchrony and decreased at increasing the interactive variability. These results align with previous findings (Launay et al., 2013; Valdesolo et al., 2010) and suggest that synchrony is associated with prosocial, affiliation, and cooperative feelings toward the other. However, trustworthiness is associated with stable interactive dynamics rather than when the partner is moderately adaptive. In other words, when the VP interacted in a "fixed" and stable way ($\alpha = 0$), the interpersonal variability was reduced, and individuals perceived more trustworthiness. This novel result suggests that higher predictability and interpersonal stability might increase the sense of trust, affiliation, and closeness resembling a "secure" interpersonal exchange. Still, contrary to our expectations, BPD traits did not modulate this association. Overall, this suggests that how the VP adapts plays a relevant role in sustaining affiliation and interpersonal stability and that relationship might restrain the effect of BPD features.

Furthermore, the perception of synchrony significantly affects aggressive behaviors and negative affect. In particular, when the perception of synchrony increased, aggressive behaviors and negative affect decreased. These results suggest the potential affective role of perceiving affiliation and collaboration in modulating negative affect and behavioral tendencies. However, according to our hypotheses, individuals with high BPD traits compared to those with low BPD traits reported higher aggressive behaviors and negative affect during the interaction and regardless of the VP adaptivity. These results align with previous studies (Miano et al., 2013; Richetin et al., 2018) suggesting an untrustworthy bias in individuals with high BPD in perceiving neutral stimuli. Moreover, replicating previous findings (Ö. Ayduk et al., 2008; Richard et al., 2022; Scott et al., 2017) individuals with high BPD traits externalized more aggressive behaviors towards the partner compared to those with low BPD traits. Overall, such emotional dysregulation might related to a reduced ability to reappraise the stimulus (Koenigsberg, 2010) at changing the VP adaptivity. This defective process might be rooted in a reduced effortful control (Rothbart & Posner, 2015) that hampers the emotional modulation, enhancing higher emotional reactivity in response to the stimulus. Moreover, those findings replicate our previous findings (Gregorini et al., under review; Chapter 1), suggesting that individuals with high BPD traits interact with higher negative emotional components regardless of VP adaptivity but also extend our results showing that individuals with high BPD traits reported higher aggressive behaviors regardless of VP adaptivity. This suggests that higher aggressive tendencies as the main core pathological features of interpersonal functioning of BPD might be associated with unstable interpersonal synchrony sustained by reduced interpersonal coordination and a split view of self and other (Clarkin et al., 2007; Kernberg & Caligor, 2005).

In conclusion, in line with the main purpose of this study, our results reveal a bidirectional effect between trustworthiness and synchrony, even though BPD traits had no significant implications on these associations. Emotionally driven stimuli with trustworthy traits increased the feeling of togetherness and closeness, at the same time, such dispositions in interaction with a well-predictable partner increased the sense of affiliation and cooperation. Therefore, the bidirectional relationship could be associated with a feeling of security and containment, which unexpectedly might reduce the presence and interference of BPD traits. Nevertheless, BPD traits significantly impacted the emotional experience in all the studies as an index of high emotional sensitivity and reactivity to social cues (i.e., Barnow, Stopsack, et al., 2009; Bortolla et al., 2019; Lynch et al., 2006).

Although the potential contribution of this study for different research veins, these findings should be considered in the context of their limitations. We used a nonclinical sample, so further research is encouraged to extend the results to a clinical sample; then, the limited ecological validity of the task might have impacted the generalization of the results to daily social interaction.

Section two

Nonverbal synchrony in psychotherapy

THE STRENGTH OF "BEING WITH"

CHAPTER 4

Being in sync in psychotherapy: a meta-analysis on the role of nonverbal synchrony on alliance and therapeutic outcome

(under review)

Gregorini, C., De Carli, P., Parolin, L., Tschacher, W., & Preti, E.

ABSTRACT

Successful interaction requires a certain degree of interpersonal coordination to create synchronized interactions. Interpersonal synchrony is a central relational aspect that sustains interactions, fostering the motivation to cooperate. The psychotherapeutic setting is a dynamic context in which the interpersonal systems of the patients and the therapist and their relationship change over time. The study of the role of nonverbal synchrony in psychotherapy is still to be determined. Here we aim to (1) analyze the strength of the relationship between nonverbal synchrony and alliance and (2) therapeutic outcome; (3) the role of the type of psychotherapeutic approaches as the moderator in this relationship. A total of k = 11 studies were selected and meta-analytically analyzed. Inclusion criteria were providing a quantitative measure of nonverbal synchrony, a measure of the alliance, and/or a measure of therapeutic outcome. The random effects model indicated that nonverbal synchrony was significantly associated with the alliance perceived by the patient (r = 0.19; 95% CI, 0.01 to 0.35; z = 2.18, p = 0.02) but not in relation to the therapeutic outcome (r = 0.22; CI, -0.04 to 0.47; z = 1.65, p = 0.09). No moderation effects were found. These findings suggest that nonverbal synchrony plays a central role in psychotherapy. However, more research is needed.

Introduction

Acting together with others is a fundamental human ability that relies upon the mutual activation of interpersonal dynamics which become spontaneously temporally aligned with each other (Schmidt & Richardson, 2008; Sebanz et al., 2007; Wiltshire et al., 2020). Synchrony entails interaction and could be measured through the temporal coordination of many nonverbal communication channels such as facial expressions, vocal tones, and body movements (Delaherche et al., 2012). Since the early relationships, synchrony has played a decisive role in building rapport and sustaining the main principles of communication and emotional regulation (Feldman & Eidelman, 2009). In fact, during synchronized interaction, infants learn how to regulate their internal states and the ability to predict and anticipate the actions of the other in a continuous process of differentiating between the self and the other (Bar-Kalifa et al., 2023; Feldman, 2017; Hoehl et al., 2021). This dynamic occurs within a dyadic face-to-face interaction and drives the development of emotional, affective, and mental states (Feldman, 2003). Moreover, many studies have demonstrated the potential role of synchrony at the relational and social level, considering the phenomenon as a "social glue" that sustains feelings of affiliation, cohesion, involvement, and prosocial attitudes (Bernieri et al., 1988; Chartrand & Lakin, 2013; Hove & Risen, 2009; LaFrance, 1979; Miles et al., 2009; Mogan et al., 2017; Rennung & Göritz, 2016; van Baaren et al., 2009; Vicaria & Dickens, 2016; Wiltermuth & Heath, 2009).

During therapy, the interpersonal systems of the patient and the therapist, as well as their physiology, change continuously over time (Kleinbub, 2017; Palumbo et al., 2017). Among such interactive dance, the patient and the therapist harmonize and coordinate their systems in an ongoing interactive process of mutual co-regulation, and thereby reciprocally influence each other (Butner et al., 2014; Dahl et al., 2016; Gelo & Salvatore, 2016; Mayo & Gordon, 2020). This interdependence and co-occurrence of interpersonal and emotional features drive the formation of the therapeutic alliance that is the essential dimension of therapy effectiveness (Horvath & Symonds, 1991; Klein et al., 2020; Koole & Tschacher, 2016). Alliance has been originally conceptualized as a *working* dimension (Greenson, 1965) and then received a definite conceptualization with Bordin (1979), who defined that alliance is based on three main components: 1) agreement of goals; 2) assignment of tasks; and 3) the development of bonds, that is the development of enough trust, respect, confidence and personal attachment between the therapist and the client to achieve the goals and take part in the task. In this sense, the alliance has been considered an unfolding process and an index of the quality of mutual collaboration that emerges during the therapeutic relationship (Kramer et al., 2020; Kramer & Stiles, 2015). Furthermore, the therapeutic relationship is a process in which the patient could experience a new and potentially positive relationship that aims at reducing patients' symptoms through trust, agreement, and the therapist's empathic ability to tune into the patient's emotional state (Horvath & Luborsky, 1993; Laverdière et al., 2019). Previous meta-analyses have identified the predictive effect of alliance on therapeutic outcomes (Castonguay et al., 2006; Flückiger et al., 2018; A. Horvath & Luborsky, 1993; Martin et al., 2000; Safran et al., 2011) and although the effect size of the association is moderate (i.e., ranging from $r = .23$ to .31) (Flückiger et al., 2020), alliance is considered as a mechanism that affects changes in the patient's symptomatology (Barber et al., 1999; Klein et al., 2003; Zilcha-Mano et al., 2018). Recently, two systematic reviews attempted to systematize research that investigated the role of nonverbal synchrony and interpersonal coordination processes in psychotherapy, revealing the complexity and multidimensional nature of the phenomenon (Atzil-Slonim et al., 2023; Wiltshire et al., 2020). However, this issue addresses the need to further research for clarification about the potentiality of nonverbal synchrony in psychotherapy. In this sense, we delved into this issue with the idea of investigating the strength of nonverbal synchrony in psychotherapy adopting a meta-analytic approach.

What do we know about nonverbal synchrony in psychotherapy?

Nonverbal synchrony and alliance

From a general perspective, interpersonal synchrony is the temporal alignment of the cooccurrence of two or more *parties* in interaction (Delearche et al., 2012; Kelso, 2009; Butner et al., 2014). In relation to body movements, six studies examined that higher synchrony was associated with high positive evaluation of therapeutic alliance (Altenstein et al. 2013; Ramseyer & Tschacher 2014, 2016; Cohen et al., 2021; Nyman et al., 2021) and self-efficacy (Ramseyer & Tschacher, 2011). However, Paulick and colleagues did not find any significant associations between synchrony and therapeutic alliance (Paulick et al., 2018). In relation to vocal synchrony, three studies investigated the association between synchrony at vocal pitch and alliance. Bryan and colleagues found a relationship between the synchrony of vocal pitch as a measure of arousal (and not temporal alignment) and alliance (Bryan et al., 2018). However, Reich and colleagues found that vocal pitch was associated with negative alliance when the therapist was leading (Reich et al., 2014). Interestingly, two studies on linguistic focus (Aafjes-van Doorn et al., 2020; Aafjes-van Doorn & Müller-Frommeyer, 2020) found a negative association between language style matching (LSM) and the alliance during sessions.

In relation to the physiological level, two studies analyzed the association between physiological synchrony and alliance. Bar-Kalifa and colleagues found that synchrony of electrodermal activity was related to alliance ratings (Bar-Kalifa et al., 2019). Moreover, Tschacher and Meier analyzed the heart rate variability (HRV) and respiration during sessions in 4 dyads (Tschacher & Meier, 2020). They found that in phase HRV synchrony and respiration were associated with the client's and therapist's alliance rating.

Nonverbal synchrony and therapeutic outcome

Another group of studies analyzed nonverbal synchrony in different modalities linked to psychotherapy outcomes as an overall outcome measure of the therapy. Four studies (Bos et al., 2002; Geerts et al., 1996; Ramseyer & Tschacher, 2001; Zimmermann et al., 2021) found a negative association between movement synchrony and symptomatology, while two studies found a positive association with goal attainment (Ramseyer & Tschacher, 2016; Nyman-Salonen et al., 2021). Two studies found that stronger nonverbal synchrony between the patient and the therapist within the sessions or interviews was related to better responsiveness (Geerts et al., 2000) to treatment or lower risk for relapse (Geerts et al., 2006). Additionally, Paulick and colleagues found that the positive association between body synchrony and clients' symptomatology only appeared in clients with depression, but not anxiety (no comorbidity) (Paulick et al., 2018). Another study found that head movement synchrony was associated with clients' better well-being, but not with body movement synchrony (Ramseyer & Tschacher, 2014). Two other studies showed significant moderating effects of therapeutic approaches in the synchrony-outcome relation (Altmann et al., 2020; Schoenherr et al., 2021). In relation to vocal synchrony, Rocco and colleagues found that stronger coordination of speech rate was associated with better treatment outcomes (Rocco et al., 2017). This result seems to be sustained by the study of Reich and colleagues in which the authors found that when the therapists' vocal pitch followed the patients' vocal pitch more strongly, an increase in symptoms was observed (Reich et al., 2014). Then seven studies analyzed the link between synchrony and empathy through vocal (n = 3) and physiological (n = 4) synchrony between the patient and the therapist. The results revealed a significant association between electrodermal activity (EDA) (Marci et al., 2007; Marci & Orr, 2006) and higher measures of empathy. Then, one study found that synchrony of respiration rate was associated with higher ratings by the therapist regarding the patient's progress in their treatment (Tschacher & Meier, 2019). Furthermore, two studies found that the coordination of the fundamental frequency of the voice as well as the matching of linguistic categories between patient and therapist were associated with higher ratings of empathy (Imel et al., 2014; Lord et al., 2015), although a large replication study failed to find such an association (Gaume et al., 2019). In relation to physiological synchrony, Prinz and colleagues found that higher synchrony measured with skin conductance predicted better outcomes in the next session, which was moderated by the interventions used (imagery rescripting vs. cognitive-behavioral) (Prinz et al., 2021).

The present meta-analysis

With this meta-analysis, we aimed to investigate the strength of nonverbal synchrony at behavioral and or vocal levels in psychotherapy, addressing the need to provide a clear investigation of the relationship among the well-known complexity of the phenomenon. Based on the theoretical framework of "In-Sync Model" (Koole & Tschacher, 2016), we would improve the view that patient-therapist nonverbal coupling strengthens therapeutic alliance, which, in turn, might positively affect the patient's emotional regulation skills and the therapeutic outcome. This sheds light on the potential link between the alignment of the body movements and the collaborative and working nature of the alliance toward the fulfillment of the therapy. Additionally, we focused on the vocal modalities since the role of vocal synchrony as a nonverbal synchrony modality might be central during bonding formation and body movements. In fact, vocal and verbal communication are the main channels through which psychotherapy is realized (Schoenherr et al., 2019, 2021) and crucial for the development of secure attachment (Feldman, 2017).

Specifically, we analyzed (1) the associations between nonverbal synchrony and the perception of alliance reported by the patients; (2) the association between nonverbal synchrony and the therapeutic outcome of therapy, and (3) the moderating role of the type of therapeutic approach on these associations.

Method

This systematic review and meta-analysis were conducted following the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) (Page et al., 2021).

Inclusion and exclusion criteria

Inclusion criteria were defined as follows. First, the studies implemented a measure of nonverbal synchrony considered in terms of behavioral synchrony and vocal synchrony during therapeutic sessions. Second, a measure of alliance and/or a therapeutic outcome measure was presented. Third, the studies provided a measure of the association between synchrony and alliance and/or therapeutic outcome. Therefore, we excluded from the search studies with no clinical intervention or psychotherapy; with samples of remitted patients, or with just one case study. In the case of eligible articles that did not report information necessary to compute an effect size, the corresponding authors were contacted to provide the missing information. We excluded one study in the meta-analysis because we did not receive the requested data.

Search method

Literature searches were conducted using the following databases: Scopus, Pubmed, Web of Science, and PsycInfo. We used the keywords "(synchronization OR coordination) AND psychotherapy", and "nonverbal synchrony AND psychotherapy". The search was not limited to studies published within a specific time. Review articles, conference proceedings, book chapters, thesis dissertations, case reports, and non-English-language materials were excluded. The latest literature check has been done in August 2023.

Data management

All 11 included studies (shown in **Fig. 1**) were double-screened and incongruences or difficulties in extracting data were discussed. Studies were coded by recording authors, year of publication, design, type, and measure of nonverbal synchrony and therapeutic variables, type of therapeutic approach, and sample characteristics. Data presentation and analyses are organized according to the therapeutic variable: alliance ($k = 11$) and therapeutic outcomes ($k = 8$). We extracted the effect sizes for the association between synchrony and the therapeutic variables. In the case of longitudinal studies, we just considered the association between synchrony and those therapeutic variables that were assessed last. For the index of nonverbal synchrony, we considered the overall measure rather than therapist-patients leading and/or following indexes (Altmann et al., 2020; Reich et al., 2014). Behavioral synchrony was assessed through the motion energy analysis (MEA) (Ramseyer, 2020) while vocal synchrony was measured by the acoustics features using the PRAAT software (Boersma & van Heuven, 2001). Since our main interest was to analyze the role of behavioral and vocal synchrony in psychotherapy, we excluded studies that referred to other modalities of interpersonal synchrony such as physiological, inter-brain, and verbal synchrony. For the measure of alliance, if the studies included a measure of alliance from both the therapist and the patient, we included only the self-report measure of the patient since we were interested in the perception of alliance reported by patients during therapy (De Bolle et al., 2010). For the assessment of therapeutic outcomes, in the case of different measures of symptoms we selected a single measure. That measure was a) the primary outcome indicated by the authors; b) the measure more indicative of interpersonal and relational functioning and c) the included general measure of symptoms' assessment. For the type of therapeutic approach, the most tested approach was cognitive-behavioral therapy (CBT) as well as other types of approaches (psychodynamic therapy (PDT), counseling, and couple therapy). According to the difference in the therapeutic process of different types of psychotherapy (Jones & Pulos, 1993), we grouped the studies into those that carried out sessions of cognitive-behavioral therapy (CBT) vs. those with psychodynamic therapy (PDT) sessions or other types of approaches, labeling them as "others".

Statistical analysis

Two different meta-analyses were conducted on studies that reported: i) the association between nonverbal synchrony and alliance; ii) the association between nonverbal synchrony and therapeutic outcome. We calculated the effect sizes based on the overall measure of the relationship between synchrony and the therapeutic variables. Data were pooled by applying random-effects models. The amount of heterogeneity was estimated using the restricted maximum-likelihood estimator (Viechtbauer, 2005). Heterogeneity was assessed using Q statistics with a significant *p*-value representing heterogeneity (Cochran, 1954); the I^2 indicated the proportion of observed variance that reflects real differences in effect size (Higgins, 2003). The presence of influential outliers in the results was detected based on Cook's distance index (Cook, 1977). Publication bias was evaluated in the funnel plot asymmetry and with trim-fill analysis to check whether additional studies needed to be imputed (Duval & Tweedie, 2000; Lin & Chu, 2018). We tested the moderation effect of the therapeutic approach (i.e., CBT vs. others) as a categorical moderator in the relationship between nonverbal synchrony and the therapeutic variables. Data analyses were performed using the software Jamovi (Version 1.6).

Results

Study selection

Database search identified 5476 articles; after duplicate removal, 4722 studies were considered. We excluded 4359 articles by title and abstract and of the remaining 363 articles, we excluded 318 since they did not relate to psychotherapy or did not include a measure related to the psychotherapeutic process. Then 45 records were potentially eligible studies, and 33 of these were excluded for reasons (shown in **Fig. 1, Table 1,** and **2** for the summary of the included studies). In total, we had 1423 subjects in k = 11 studies of which k = 8 included a quantitative measure of the relationship between nonverbal synchrony and both therapeutic variables (i.e., alliance and therapeutic outcome). We conducted separate analyses for the association between nonverbal synchrony and alliance and the association between nonverbal synchrony and therapeutic outcome.

Study characteristics

<u>Associations between nonverbal synchrony and alliance</u>

Studies that analyzed the effect of nonverbal synchrony on alliance were k = 11 (shown in **Table 1**). Nine of these had a longitudinal design and two had a cross-sectional design. Nine included a measure of behavioral synchrony measured with MEA and two studies included a measure of vocal synchrony (analyzed with PRAAT). In all studies, alliance was measured with self-reports such as the Working Alliance Inventory (WAI), Working Alliance Inventory Short Form (WAI-SF) (Hatcher & Gillaspy, 2006), Client Working Alliance Inventory Short Form (CWAI-SF) (Tracey & Kokotovic, 1989), the Helping Alliance Questionnaire (HAQ) (Luborsky et al., 1996), the Rupture Resolution Rating System (3RS) (Eubanks et al., 2019), Bern Post-Session Report (BPSR-P) (Flückiger et al., 2010), the Session Evaluation Questionnaire (SEQ) (Stiles, 1980) and the Session Rating Scale (SRS) (Duncan et al., 2003). In k = 4 CBT was used as a therapeutic approach; k = 1 used CBT and PDT; k = 2 PDT; k = 1 adolescent identity treatment; k = 1 couple therapy; k = 1 counselling and k = 1 "crisis intervention" (specific for emergency clinical encounters (Bryan et al., 2018). The forest plot of this meta-analysis is shown in **Figure 2(a)**. Correlation coefficient based on the random-effects model reported a small but significant effect size (r = 0.19; 95% CI, 0.01 to 0.35; $z = 2.18$, $p = 0.02$). Test for homogeneity among studies showed heterogeneity between the studies ($Q_{(11)} = 51.58$, $p < .0001$, $tau^2 = 0.06$, $I^2 = 83.91\%$). Neither the rank correlation ($p = .67$) nor the regression test ($p = .98$) indicated any funnel plot asymmetry. The trim and fill analysis did not detect any missing studies (shown in **Figure 2(b)**). The moderation effect of the type of therapeutic approach (CBT vs. others) was tested and no significant effect emerged on the relationship between synchrony and alliance (b = -0.04, SE = 0.16, $p = .79$, CI, -0.37 to 0.28). Finally, since Cook's distance detected that one study (Reich et al., 2014) overly influenced the overall outcome, we additionally ran the analysis again without this study. Results showed a larger and significant effect size (r = 0.24; 95% CI, 0.12 to 0.36; $z = 3.94$, $p < .001$). According to the Q-test the studies seem to be heterogeneous ($Q_{(11)} = 29.08$, $p < .001$, $tau^2 = 0.02$, $I^2 = 66.74\%$). Neither the rank correlation nor the regression test indicated any funnel plot asymmetry (p = 0.40 and p = 0.96, respectively).

Associations between nonverbal synchrony and therapeutic outcome

Studies that tested the association between nonverbal synchrony and therapeutic outcome were $k = 8$ (shown in **Table 2**). Six of these had a longitudinal design while two had a cross-sectional design. These studies presented a measure of behavioral synchrony ($k = 7$) measured with the MEA and a measure of vocal synchrony ($k = 1$) assessed with the PRAAT. Therapeutic outcomes were assessed with the Inventory of Interpersonal Problems (IIP and IIP-12-Short Form) (Horowitz et al., 1988; Lutz et al., 2006), the Beck Depression Inventory (BDI-II) (Beck et al., 1996), and other measures of global outcomes' assessment such as Goal Attainment Scaling (GAS) (Kiresuk et al., 2014), Levels of Personality Functioning Questionnaire (LoPF-Q)(Goth et al., 2018), and the Clinical Outcomes in Routine Evaluation - Outcome Measure (CORE-OM) (Duncan et al., 2003). Regarding the therapeutic approach, $k = 4$ studies used CBT, $k = 1$ study used CBT and PDT, $k = 1$ adolescent identity treatment, $k = 1$ couple therapy and $k = 1$ counseling. The forest plot (shown in **Figure 3(a)**) of the selected studies showed an overall medium but insignificant effect size (r = 0.22; CI, -0.04 to 0.47; $z = 1.65$, $p = 0.09$). According to the heterogeneity test, studies are heterogeneous ($Q_{(8)} = 83.91$, $p < 0.0001$, $tau^2 = 0.12$, $I^2 = 91.32\%$). According to Cook's distances, none of the studies with negative effect sizes were overly influential. Neither the rank correlation nor the regression test indicated any funnel plot asymmetry ($p = 0.29$ and $p = 0.06$, respectively) (shown in **Figure 3(b)**). CBT vs. other types of therapies did not moderate the relationship (b = 0.39, SE = 0.24, CI, -0.08 to 0.86, $p = 0.10$).

Discussion

In this meta-analytic study, we investigated the strength of the relationship between nonverbal synchrony (behavioral and vocal) and therapeutic alliance and outcome. Regarding the alliance, we found that nonverbal synchrony was significantly associated with the patient's perceived sense of alliance even though the effect was relatively small. The differences in effect sizes were moderate and the test for homogeneity indicated significant heterogeneity since the effect sizes ranged from small to large.

In relation to the studies that investigated the association between behavioral synchrony and alliance, we found a negative association in only one study (Zimmermann et al., 2021). Moreover, consistent with studentized residuals and Cook's distances, one study that presented a relationship between vocal synchrony and alliance showed a strong negative effect size that influenced the overall result (Reich et al., 2014). In this sense, we conducted an additional analysis without that study, and we found a medium-sized association between synchrony and alliance. Then, the moderation analysis of the therapeutic approaches in the tested association was not significant.

Regarding the association between nonverbal synchrony and therapeutic outcome, we found that the strength of the relationship between the two variables was medium size but not significant. Effect sizes ranged from small to medium and were significantly heterogeneous. Despite the non-significant result, the direction and size of the association were as expected.

Overall, our results highlight that nonverbal synchrony, especially at the behavioral level was associated with the perception of the alliance as an index of collaboration, reciprocity, and involvement of the patient in the therapy. This is a novel result and suggests that the ability to anticipate the other actions' during therapy could increase behavioral alignment and has a potential role in the building and development of the therapeutic bond. Moreover, these results are in line with the In-Sync model (Koole & Tschacher, 2016) and suggest that behavioral synchrony as a relational phenomenon strengthens the active collaboration between therapist-patient and has an impact on the development of the alliance as a central component of the therapeutic process. Furthermore, from a broad perspective, this result supports the positive view of interpersonal synchrony within the interaction as a key relational dimension (Bernieri et al., 1988; Chartrand & Lakin, 2013; Hove & Risen, 2009; LaFrance, 1979; Miles et al., 2009; Mogan et al., 2017; van Baaren et al., 2009).

Additionally, our findings suggest that different forms of nonverbal synchrony have a specific and distinct role in the psychotherapeutic setting. In fact, vocal synchrony was found to be potentially less satisfactory for creating a relationship based on trust and agreement compared to behavioral synchrony. This is in line with the previous idea that vocal synchrony could be considered a byproduct of the relationship (Reich et al., 2014) and be more suitable to have been affected by the interpersonal impairments of the patients with negative outcomes on the alliance.

Regarding the therapeutic outcome, the results revealed no significant association with nonverbal synchrony. On one hand that could stem from the very small number of studies that we included in the final analysis; on the other hand, this result could suggest that interpersonal coordination dynamics might have a direct impact on the micro-outcome (alliance) levels of the therapeutic process rather than on the fulfillment of the relational process. This could be also in line with the idea that interpersonal synchrony is a dynamic process that might be more related to the relational features that occur during the formation of the therapeutic relationship instead of the result. However, according to previous studies that highlighted the role of the alliance in relation to the therapeutic outcome (Barber et al., 1999; Blatt et al., 1997; Frieswyk et al., 1986; Martin et al., 2000; Stiles, 1980; Hilliard et al., 2000; Horvath & Symonds, 1991) as well as the definition of the key elements for the development and maintenance of the therapeutic alliance (Crits-Christoph et al., 1993; Horvath & Greenberg, 1989; Mallinckrodt & Nelson, 1991; Ogrodniczuk & Piper, 1999; Price & Jones, 1998), our findings would suggest taking into account the role of the alliance as a mediator in the relationship between synchrony and therapeutic outcome.

In relation to the result of the moderation role of different therapeutic approaches, we suppose that nonverbal synchrony might be not influenced by the therapeutic approach but by more dynamic features related to the dyadic interchange during the therapist-patient relationship. In this sense, we assume that the patient-therapist synchrony could be moderated by the severity of the psychopathology and interpersonal function (Marble et al., 2019) as well as the personal qualities of the therapist (Ackerman & Hilsenroth, 2003; Parolin et al., 2017).

Conclusion

In conclusion, we quantitatively analyzed a still unexplored relationship between nonverbal synchrony and therapeutic factors. We found that nonverbal synchrony, mainly at a behavioral level, could facilitate the development of the therapeutic bond (i.e., trust, mutual agreement, responsiveness), while no associations were found with the therapeutic outcome. In this way, synchrony seems to enhance the sense of trust and collaboration that develops during therapy and promote alliance (Gaston, 1990; Horvath & Luborsky, 1993). Overall, the results of this meta-analysis can also have relevant clinical implications. Nonverbal synchrony was found to be associated with the alliance as an active and purposeful collaboration that promotes change through the affective bond development between patient and therapist. To ensure that interactive development is positive and functional, it is therefore important that the therapist be able to coregulate the emotional states to reach a *congruency* even more oriented to restore the interpersonal functioning of the patient. In this sense, “being in sync” in psychotherapy would be considered a relational aspect that improves the potential of the therapeutic relationships at different levels under a collaborative and mutual perspective that lets patients experience trust and protection. These findings provide ideas of interest for future exploration. Further research should investigate (1) the role of other modalities of synchrony and (2) individual characteristics; (3) whether nonverbal synchrony indirectly improves and promotes therapeutic outcomes in terms of symptom reduction through alliance and (4) the role of synchrony in repairing ruptures.

However, this study has limitations. The first limitation is that we considered the alliance measures reported only by the patients. Second, we considered the therapeutic outcome in terms of general symptomatology instead of symptom reduction. Third, the moderation analysis of the therapeutic approach was statistically less reliable since it needed more studies and higher sample sizes to be conducted. Fourth, we need to consider our findings in the context of study characteristics as we included a small number of studies, with limited sample size, and not all the participants had a clinical disorder. We then considered all the different measures for the assessment of alliance and therapeutic outcomes without specific restrictions. Based on this, we suggest that more studies are needed to provide a generalization of the results as well as to compute a reliable moderation analysis of the role of different therapeutic approaches. Fifth, in both analyses the moderation test did not report any significant results. This might be due to methodological reasons since we grouped sessions of the cognitive-behavioral approach compared to all others (i.e., psychodynamic, couple therapy, counseling). Finally, at the methodological level, it is still difficult to reach a univocal definition of synchronization and it is challenging to study two dynamic rather than static constructs such as alliance and therapeutic outcome as they are affected by (1) the changes that occur within the therapy; (2) by the time of the assessment as well as the interpersonal functioning of the patient and (3) patient's motivations, expectations, involvement, and representations.

Table 1. Study characteristics on the association between nonverbal synchrony and alliance

Study	Study characteristics					Sample	
	Design	Modality_NVS	Measure_NVS	Measure of alliance	Therapeutic	N	Type of Sample
Altmann et al. (2020)	L	BS	MEA	HAQ	CBT/PDT	267	C
Bryan et al. (2018)	CS	VS	PRAAT	WAI-SF	CRISIS	54	C
Cohen et al. (2021)	L	BS	MEA	WAI	PDT	86	C
Deres-Cohen et al. (2021)	L	BS	MEA	3RS	PDT	75	C
Nyman-Salonen et al. (2021)	L	BS	MEA	SRS	COUPLE	11	NC
Paulick et al. (2018)	L	BS	MEA	HAQ	CBT	143	C
Ramseyer & Tschacher (2011)	CS	BS	MEA	BPSR-P	CBT	70	C
Ramseyer & Tschacher (2014)	L	BS	MEA	BPSR-P	CBT	70	C
Ramseyer, F.T. (2020)	L	BS	MEA	BPSR-P	CBT	12	C
Reich et al. (2014)	L	VS	PRAAT	CWAI-SF	COUNSELING	52	NC
Zimmermann et al. (2021)	L	BS	MEA	SEQ	AIT	16	C

Note: Design: L= Longitudinal; CS= Cross-sectional; Modality_NVS (nonverbal sync): BS= behavioral synchrony; VS= vocal synchrony; Measure_NVS: MEA=motion energy analysis; PRAAT= software for analysis of phonetic and speech features; Measure of alliance: WAI=Working Alliance Inventory, BPSR-P= Bern Post-Session Report patient, HAQ= Helping Alliance Questionnaire, 3RS=The Rupture Resolution Rating System, WAI-SF=Working Alliance Inventory- Short Form, CWAI-SF=Client Working Alliance Inventory- Short Form; SEQ=Session Evaluation Questionnaire; SRS= Session Rating Scale; Therapeutic approach: CBT=Cognitive Behavioral Therapy; PDT= Psychodynamic Therapy; AIT=Adolescent Identity Treatment; Type of sample: C=clinical; NC=non clinical

Table 2. Study characteristics on the association between nonverbal synchrony and therapeutic outcome

Study	Study characteristics					Sample	
	Design	**Modality_NVS**	**Measure_NVS**	**Therapeutic outcome**	**Therapeutic approach**	**N**	**Type of sample**
Altmann et al. (2020)	L	BS	MEA	IIP	CBT/PDT	267	C
Nyman-Salonen et al. (2021)	L	BS	MEA	CORE-OM	COUPLE	11	NC
Paulick et al. (2018)	L	BS	MEA	IIP-12	CBT	143	C
Ramseyer & Tschacher (2011)	CS	BS	MEA	IIP	CBT	70	C
Ramseyer & Tschacher (2014)	L	BS	MEA	GAS	CBT	70	C
Ramseyer, F.T. (2020)	L	BS	MEA	IIP	CBT	12	C
Reich et al. (2014)	CS	VS	PRAAT	BDI-II	COUNSELING	52	NC
Zimmermann et al. (2021)	L	BS	MEA	LoPF-Q 12–	AIT	16	C

Note: Design: L= Longitudinal; CS= Cross-sectional; Modality_NVS (nonverbal sync): BS= behavioral synchrony; VS= vocal synchrony; Measure_NVS: MEA=motion energy analysis; PRAAT= software for analysis of phonetic and speech features; Therapeutic outcome: BDI= Beck Depression Inventory; IIP/IIP-12= Inventory of Interpersonal Problems; GAS= Goal Attainment Scaling; LoPF-Q 12–18= Levels of Personality Functioning Questionnaire; CORE-OM= Clinical Outcomes in Routine Evaluation-Outcome Measure; Therapeutic approach: CBT=Cognitive Behavioral Therapy; PDT=Psychodynamic Therapy; AIT=Adolescent Identity Treatment; Type of sample: C=clinical; NC=non clinical

Figure 1. Flow Diagram of study selection.

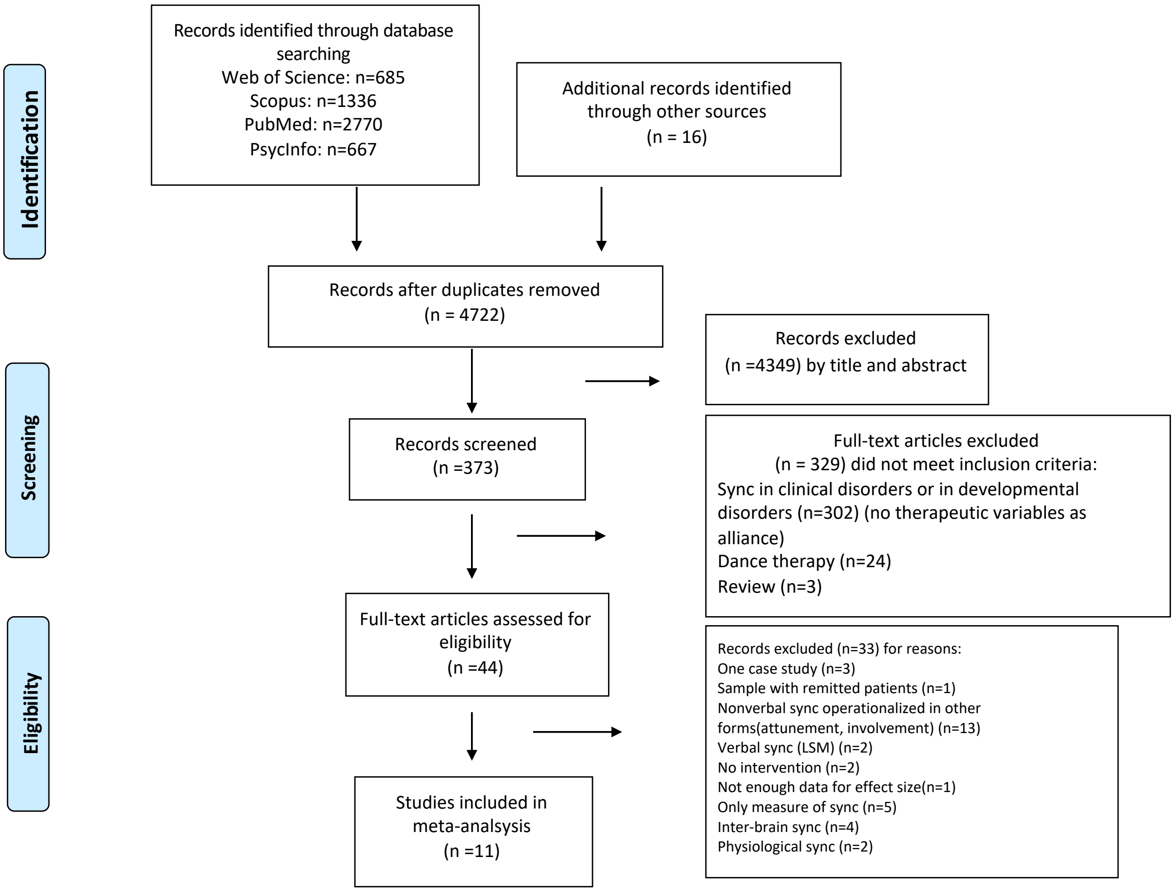


Figure 2(a). Forest plot of nonverbal synchrony and alliance

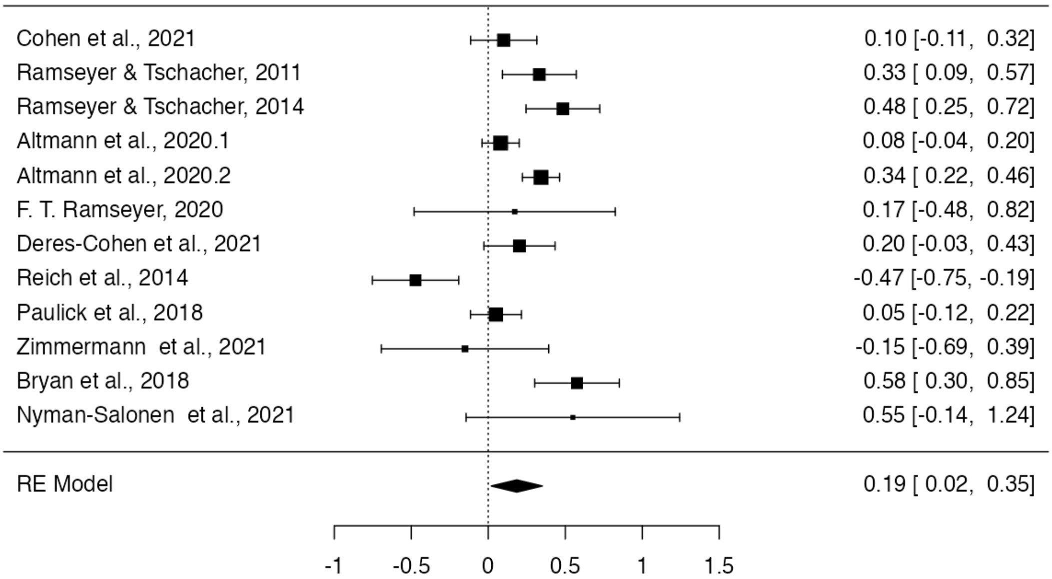


Fig. 2(b). Funnel plot for asymmetry in studies on the relationships between nonverbal synchrony and alliance

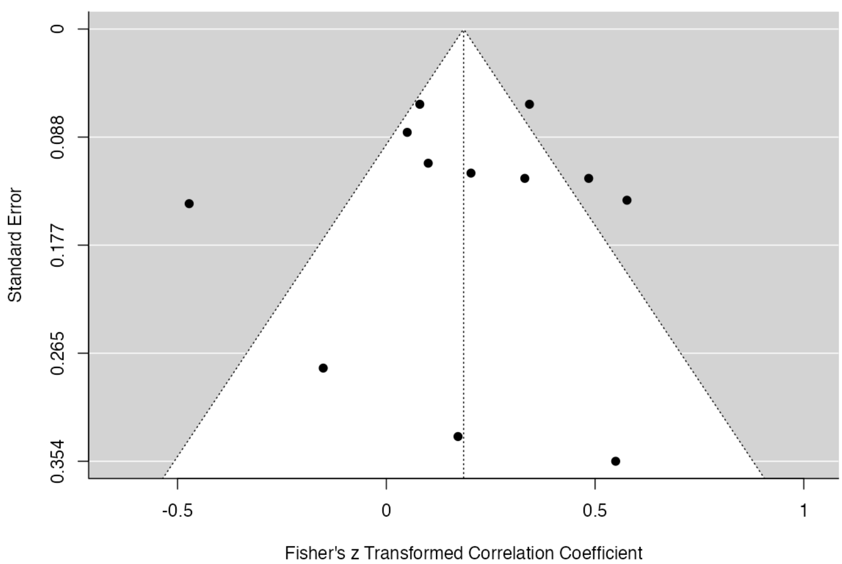


Figure 3(a). Forest plot of nonverbal synchrony and therapeutic outcome

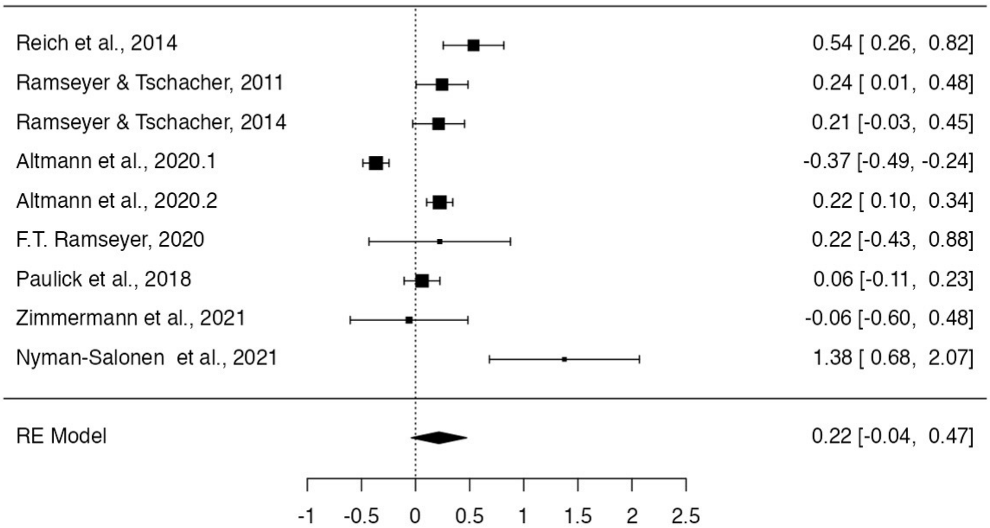
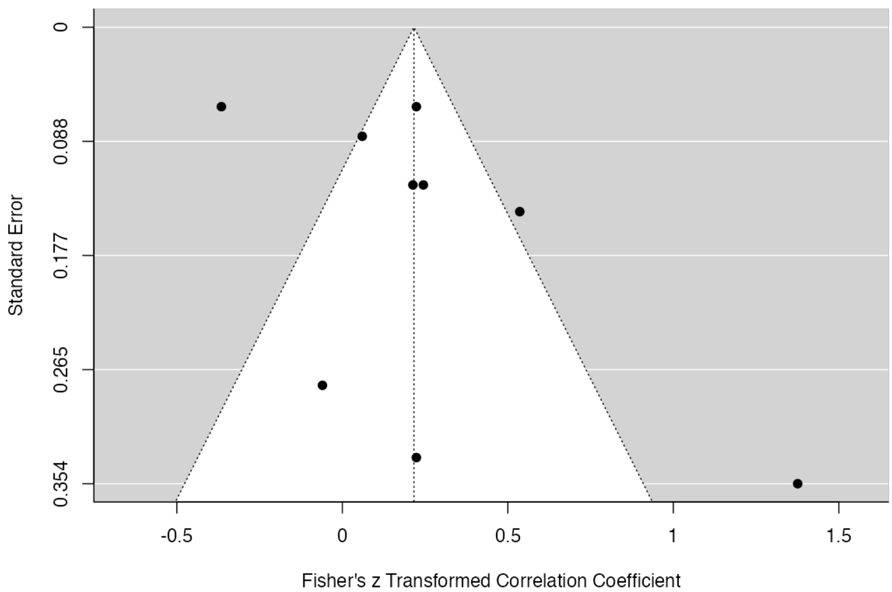


Fig. 3(b). Funnel plot for asymmetry in studies on the relationships between nonverbal synchrony and therapeutic outcome



General discussion

CONCLUSION AND FUTURE DIRECTIONS

General discussion

The present thesis aims to investigate whether pathological individual dispositions related to BPD modulate the processes of interpersonal coordination that enable interpersonal synchrony to emerge. Moreover, a second aim referred to analyze whether a specific modality of synchrony - nonverbal synchrony - would sustain therapeutic relationships and clinical change. In the first section, we propose an empirical approach testing whether high BPD traits would be associated with impairments in synchronized interactions with a variable adaptive-responsive partner that might be rooted in the cognitive and affective schemas of an insecure-disorganized attachment relationship. Specifically, we tested how interpersonal vulnerabilities and emotional dysregulation might hamper the interaction and the elaboration in "real-time" of the social cue. Then, based on the psychodynamic view of therapy as an 'intersubjective' meeting where the internal working models emerge, we proposed how nonverbal synchrony could play a role, providing a metanalytic analysis of the relationship between nonverbal synchrony and alliance and the therapeutic outcome. In this sense, combining those findings and extending existing literature, we present a potential view of interpersonal and nonverbal synchrony as a relational phenomenon that might improve interpersonal functioning and emotional regulation within therapy.

Which mechanisms underpin interpersonal coordination?
THE ROLE OF HIGH BPD TRAITS

In the first section of the thesis, we investigated whether high levels of BPD traits reflecting high affective disturbances, disturbed cognition, impulsivity, and unstable relationships (Lieb et al., 2004; Skodol et al., 2002) could interfere with the processes implicated in interpersonal coordination and interpersonal synchrony at behavioral, neural and affective levels. From a methodological standpoint, we developed a finger-tapping task in order to provide the participants with an interactive experience where the synching ability of a virtual partner (VP) was manipulated to produce an interactive response (tone) that varied in terms of temporal adaptivity (Fairhurst et al., 2013). We then studied the behavioral and neural correlates of this task and the bidirectional effect of VP identity manipulation.

In Chapter 1, in line with our exploratory hypotheses, we found that the levels of BPD traits in interaction with the VP adaptivity had a moderation effect on the behavioral performance of asynchrony and variability. This suggests that individuals with high levels of BPD traits compared to those with low levels of BPD traits interacted with more difficulties in anticipating and adapting to the VP and more instability even when the VP reduced the asynchronies during the interaction. Specifically, higher levels of establishing unstable relationships rooted in higher sensitivity to rejection and negative expectations related to others (negative relationships subscale) were associated with more variability in staying in synchrony regardless of the level of the partner's responsiveness. Furthermore, in line with our main hypothesis, individuals with high BPD traits compared to those with low levels of BPD showed a higher variability in predicting when the next tone would occur, regardless of how the VP adapted. Those behavioral results suggest that even when the VP was reducing asynchrony and interacted with a moderate level of adaptation, echoing *"the high-but-imperfect"* (Jaffe et al., 2001; Meltzoff, 2007), individuals with high BPD traits compared to those with low BPD traits showed higher impairments in anticipating and adapting to the other's actions as well as a higher instability in coordinating and stay in synchrony with the partner. Such interpersonal dysfunction suggests a higher impairment in individuals with high BPD traits in co-representing self and other actions and internally simulating the other's action, resulting in a reduced mutual adaptation. Moreover, these impairments might reflect the cognitive-affective dispositions of individuals with high BPD traits rooted in an insecure-disorganized attachment. Despite being far beyond the reach of the present thesis, we could speculate that individuals with high BPD traits might tend to interact with higher levels of "disorganization" at the behavioral level (Lyons-Ruth et al., 1999; Lyons-Ruth & Spielman, 2004) resulting in reduced interpersonal coordination. In this sense, those individuals interact with a reduced ability to integrate self and other representation and to temporally align to the other's action to reach the "we-mode" (Heggli, Cabral, et al., 2019; Kourtis et al., 2019; Sebanz & Knoblich, 2009). In this sense, the achievement of "we mode" is sustained by a well-balanced integration and segregation between self and other actions. Specifically, the ability to mentally 'represent' the mutual action (Vesper et al., 2017) would sustain interpersonal coordination and lead to interpersonal synchrony through a continuous mutual adaptation (Heggli, Konvalinka, et al., 2019; Konvalinka et al., 2010). Considering our results, we speculate that the impaired mental representation of self and others (Kernberg & Caligor, 2005) in individuals with high BPD traits would drift the interpersonal coordination processes to higher asynchrony and instability and, in turn, hamper the possibility of reaching a mutual adaptation.

Moreover, in line with our main hypotheses, individuals with high BPD traits compared to those with low BPD traits perceived the interaction with a lower sense of "feeling on the same wavelength" and higher negative affect regardless of how the VP adapted. Such negative emotional experiences of synchrony could reflect the difficulties in modulating the affective responses in relation to the social cue that might be rooted in higher rejection sensitivity (Ayduk et al., 2008), reduced trust towards the other, and reappraisal of the social stimulus. In this sense, traumatic and neurobiological vulnerabilities would hamper the experience of modulating the affect concerning the evaluation of the partner (Hepp et al., 2017; Koenigsberg, 2010). Overall behavioral and affective results suggest that such impairments could be the "developmental outcome" of early defective communication and temporal coordination characterized by a reduced experience of responsiveness and the downfall of the interpersonal and emotional organization.

Furthermore, according to Kernberg (1967,1976), the rigidity of the descriptive aspects of the personality functioning in borderline personality organization concerning the structural domain of 'object relations' might have hampered the possibility of interacting with flexibility. In other words, the pathological levels of the features related to the internalization of the 'object' through the development of dysfunctional internal working models could impact the expectations and the ability to integrate the self and the other in a functional and realistic sense. Moreover, these results suggest that individuals with high BPD traits might interact driven by reduced mentalization sustained by a split and polarized view of the other that, in turn, damages the information processing, the "we mode," and the affect regulation. In our case, the VP would be the 'object' that reactivates the unstable experience and, in turn, representations of self and the self in relation to the other (Kernberg & Caligor, 2005), echoing a non-marked mirror experience (Fonagy, 2002; Gergely, 2004). Along with these findings, and to better investigate the impairments of staying in synchrony in individuals with high BPD traits, as shown in Chapter 1, in Chapter 2, we found that partially in line with our hypothesis, individuals with high levels of BPD traits showed reduced mu suppression at a specific component (10 Hz) of the range 9-13 Hz compared to individuals with low BPD traits when involved in synchronized interaction. This indicated that individuals with high BPD traits compared to those with low BPD traits interacted with impairments in the action-perception loop (Hari, 2006; Hari & Kujala, 2009) that might be underpinned by a reduced sensorimotor integration of self and other actions resulting from self and other mental disturbances (Bender & Skodol, 2007; Kernberg & Caligor, 2005). That might underlie the polarized and split views of self and other's representations (Caligor et al., 2023; Kernberg & Caligor, 2005), generating a chaotic identification and impairments in differentiating between self and other. Such findings would give more insight into the mechanisms underpinning the action-perception loop and our previous behavioral results, based on the view that pathological dispositions might play a role in modulating the processes of self and others' actions representation. From a complementary perspective, the unstable and less coherent sense of self might be rooted in a lack of affective mirroring (Gergely & Watson, 1996, 1999) and reduced mentalization (Fonagy & Bateman, 2008; Fonagy & Target, 1997). Furthermore, a reduced ability to integrate self and others might be sustained by a pre-mentalizing mode that might generate an imbalance between the poles of mentalization (self-other; cognitive-emotion; internal-external) (Fonagy & Luyten, 2009;

Luyten & Fonagy, 2015). However, we found an interesting but unexpected result: individuals with high BPD traits reported higher cooperation at increasing VP adaptivity. This result suggests that individuals with high BPD traits might show a hypermentalization process (Sharp, 2014) in relation to how the VP adapted, as well as a hyperactivation of the attachment that might lead to a sense of holding and "feeling with" that increased at increasing the partner's adaptivity. Along this line, we speculate that being in interaction with a 'hyper follower' VP (overly adaptive) might resemble a feeling of 'overinclusion' that might be perceived as "fair" interactive conditions resulting from an "idealization" of the other rooted in the pathological spit view of self and other (Clarkin et al., 2007). Therefore, considering those findings, in Chapter 3, we tested synchrony's affective and social components, exploring whether there was a bidirectional effect between trustworthiness and synchrony and the role of BPD traits. In study 1 and 2, we found that trustworthiness affected not only the interpersonal synchrony but also the perception of synchrony; vice versa in study 3. On the one hand, this suggests a bidirectional effect between affiliative feelings and the ability to co-represent self and others during a synchronized interaction. On the other hand, this extends our previous findings, suggesting that the behavioral response of the partner plays a role at the affective level in promoting affiliation. Moreover, we observed that a well-predictable and regular VP increased trustworthiness compared to an adaptive VP. In other words, a sense of protection and collaboration was enhanced when the partner regularly generated expectations about when the next action would be presented, and, in turn, the interactive variability was low. This suggests that such interaction conditions might resemble a "secure" relationship and promote affiliation. In turn, such positive feelings seemed to sustain interpersonal stability and then facilitate a mutual adaptation and a co-representation and integration of self and other mental representations. However, BPD traits had no significant implications in these associations. This unexpected result seems to open new reflection in relation to the potential of such interdependence as a dynamic that might reduce the interference of BPD features during the interaction. In this sense, the nonverbal emotional channel and how the partner adapts might be involved at a complementary level during interaction (i.e., therapy) toward collaboration and affective feelings (Philippot et al., 2003; Scheidt et al., 2021; Schoenherr et al., 2021).

Furthermore, individuals with high BPD traits were associated with a higher negative emotional experience in all the studies, suggesting a higher sensitivity and reactivity to social stimuli driven by disturbed cognitive and affective processes. These results suggest that individuals with high BPD features are associated with a reduced ability to reappraise the stimulus at changing the trustworthiness (study 1 and 2) and the VP manipulations (study 3). Such defective processes might be rooted in a reduced effortful control that hampers the emotional modulation, enhancing higher emotional reactivity in response to the stimulus (Koenigsberg, 2010; Rothbart & Posner, 2015) and emotional sensitivity to the social stimuli (i.e., Barnow et al., 2009; Bortolla et al., 2019; Lynch et al., 2006). Overall, those results suggest the potential and bidirectional interdependence trustworthiness and synchrony. Specifically, interacting with a trustworthy partner enhances the "feeling with," and at the same time, this togetherness and interpersonal closeness predicts a sense of affiliation and cooperation, especially if the other interacts with a certain level of predictability. Such interpersonal dynamics might have relevant implications in therapy within the therapeutic relationship promoting alliance (Baier et al., 2020; Martin et al., 2000) and epistemic trust (Fonagy & Allison, 2014; Milesi et al., 2023) while working in a "we-mode" interpersonal stance.

Nonverbal synchrony in psychotherapy
THE STRENGTH OF "BEING WITH"

In the second section, we investigated meta-analytically the potential role of nonverbal synchrony at behavioral and vocal levels in psychotherapy. We explored the strength of the association between nonverbal synchrony in patient-therapist interaction with the alliance and the therapeutic outcome. Specifically, we focused on two different modalities of nonverbal synchrony: behavioral and vocal. Our meta-analysis revealed a significant relationship between nonverbal synchrony and the alliance perceived by the patient but not with the therapeutic outcome. Notably, in relation to the association between nonverbal synchrony and alliance, when removing only one study presented a measure between vocal synchrony and alliance, we observed that the relationship between nonverbal synchrony measured at behavioral synchrony and alliance increased. However, we found a higher heterogeneity between the studies that might affect the overall results. In addition, the type of therapeutic approach did not moderate the associations.

Nevertheless, those results shed light on the potential role of nonverbal synchrony in psychotherapy, revealing that the behavioral matching compared to the vocal level was mainly associated with the perception of alliance. We speculated that the harmony achieved through the movements of the body and the gestures (i.e., Ramseyer & Tschacher, 2011, 2014) might generate a sense of closeness and of a "we mode" that might resemble the sense of "holding" of a secure attachment relationship. In turn, such interactive dynamics might enhance the alliance rather than a matching at the vocal level. In this sense, our results suggest that not all types of nonverbal synchrony could be effective in "working" with the patient. Along with these findings, we speculate that nonverbal synchrony might bolster the affective components of the therapeutic relationship while the therapist might be perceived as the "true companion" (Bowlby, 1988). However, even though this study could be a novel and important contribution to clinical research and intervention, more research is encouraged. Future research would analyze whether other modalities of nonverbal synchrony could be associated with therapy and whether the perception of alliance from the therapist's perspective might be implicated. Then, to extend our results, further studies would explore whether the therapeutic outcome would mediate the relationship between nonverbal synchrony and alliance. In addition, one of the still open questions is, what could be the role of synchrony when ruptures occur, and what could be the role of synchrony when working with patients with severe disorders?

A "window" into the theoretical perspectives

Empirical and meta-analytical findings shed light on a relevant and timely topic that would increase clinical research at the interface of theoretical perspectives. Our empirical results enhanced how the pathological rigidity of the psychological structures as organizers of the behavior, perception, and subjective experience might hamper interpersonal coordination and interpersonal synchrony. Moreover, we found an interdependence between interpersonal synchrony and affiliative and social feelings. In addition, nonverbal synchrony plays a role in therapeutic relationships, enhancing the therapeutic alliance.

Consistent with these lines, our results suggested that cognitive and affective schema rooted in the attachment and the development of "identity diffusion" (Agrawal et al., 2004; Kernberg & Caligor, 2005; Levy, 2005) might interfere with the processes underpinning interpersonal coordination and interpersonal synchrony at behavioral, neural, and affective levels. Specifically, insecure or disorganized representational states concerning traumatic attachment relationships might underpin the higher asynchrony and instability that emerged during self and other interactions associated with high BPD features. Specifically, the early interaction with an unresponsive and inaccessible mother would have hampered the expectancies of procedural representation of other's actions and intentions (Lyons-Ruth et al., 1999; Lyons-Ruth & Spielman, 2004) and the experience of knowing the other's mind and making oneself known to the other (Fonagy & Target, 1997). In turn, such dysfunctional "collaborative dialogue" and the experience of not being seen might lead to internalizing contradictory interactive models and a low ability for interpersonal emotional regulation (Beebe & Lachmann, 2013). In line with this, higher negative affectivity has been found to accompany the higher behavioral disorganization of individuals with high BPD features during the interaction. In this sense, we speculate that the hypersensitivity to interpersonal stimuli as the developmental outcome of disorganized attachment would intensify the negative affect, and expectancies of rejection and hamper the reappraisal of the social cue even when adaptive. In other words, even when the interactive stimulus was presented with positive and adaptive interpersonal characteristics, high BPD features were associated with higher negative affect and aggressive behaviors. However, such representation of the "other" as part of a developmental, traumatic environment would hamper, on the one hand, the experience of the other as a trust companion, while on the other hand, the perception of the interactive shared setting as a "secure base" and, in turn, lead to mistrust (Allen, 2013; Milesi et al., 2023).

Furthermore, along with this theoretical framework, the experience of non-markedness and ostensive cues might have hampered the possibility of emotional regulation sustaining the internal fragmentation and incoherent sense of self. Moreover, the disorganization at interpersonal and affective levels would reveal the disturbances in the identity's domain where the self is unstable, and the structure of the mental representation of self and self in relation to the other is less integrated, malevolent, and less differentiated. Such internal 'disgregation' would hamper the experience of "feeling like me" (Meltzoff, 2007), resulting from the representation of self and others as embedded in simultaneous positive and negative emotions, causing a split in the organization of the experience of the self and aggressive tendencies toward the partner. Therefore, we suggest that during therapy, as a space that would enable the patient to experience a secure relationship while exploring the internal working models (Daniel, 2006; Duarte et al., 2022), a synchronized interaction might sustain the affective levels of the therapeutic relationships. Synchrony at the nonverbal level might underpin the collaborative processes rooted in the alliance that are the foundation of the dyadic therapeutic interaction. This might provide emotional regulation working in a state-like situation but also on the trait-like (Fisher et al., 2023; Fonagy et al., 2015). In other words, the behavioral "we mode" resulting from interpersonal or nonverbal synchrony would be accompanied by a new "we-mode" at *cognitive* alignment, promoting social adaptation and learning. In turn, the experience of "new significances" and a constant re-elaboration of self in relation to others would be presented within a "working together" interpersonal dimension sustaining a "feeling close."

Why the virtual partner?

As presented in the introduction, the virtual partner allowed us to widely manipulate the degree of temporal adaptivity working on temporal series through well-controlled behavior analysis. On the one hand, this type of interaction would recall the mechanisms underpinning interactive contingencies and auto-contingencies (Beebe & Lachmann, 2013) studied in developmental research during the early dyadic interaction. On the other hand, and closer to the purpose of this thesis, this type of social interaction allowed us to understand better the social cognition processes that might underpin interpersonal coordination along with the affective components that might drive the evaluation of the stimulus towards a reduced emotional regulation and increasing the negative affect. Furthermore, from a multidisciplinary approach, we combined a cognitive view of the interaction flow sustained, for instance, the action-perception loop and simulation of the other's action, but at the same time highlighting the pathological individual dimensions as a reflection of cognitive and affective schema rooted in early interactive interactions and caregiver environment. In this sense, we enhanced the role of how the affect or even better, the non-modulated early affect that emerges when the self "meets the other," shapes the interpersonal dynamics in terms of reduced synchrony and high negative affect. Such an approach should be an attempt to combine different perspectives while studying the same interpersonal phenomenon as the result of interpersonal coordination processes that require an interdependence of high meta-cognitive abilities but grounded in different goal-driven perspectives. This might lay the ground for new explorations in a more ecological way. However, the main disclosure of this thesis is that the quality of what 'occurs behind' the interpersonal process might need a multidisciplinary effort to increase research and, in a prospective way, why not the clinical practice?

General limitations and strengths

This thesis has several limitations but also strengths. In section one, the main limitation is that we used non-clinical samples, so the generalization of the results needs to be considered within this constraint, and further investigations are encouraged. However, we increased experimental research concerning psychopathology and laid the ground for other investigations in clinical samples. Further, there are methodological aspects that need to be considered. From a broad perspective, interpersonal synchrony is a complex and multifaceted construct that still lacks a theoretical framework. However, we adopted a well-controlled experimental task grounded on a computation model that allowed us to study interpersonal synchrony passing through the main mechanisms that sustain such dynamic in line with the purposes of this thesis. Moreover, using a virtual partner is a constraint that would drive toward uncertain generalization of the results among clinical perspectives and interpretations. Nevertheless, these distinctive features are also the main strength of this thesis. Keeping this multidisciplinary approach, we ascertained how pathological features are implicated concerning such manipulation, echoing the contingency processes and, in turn, providing a novel contribution to different research veins. Furthermore, in section two, we analyzed the effect of a slightly different type of interpersonal synchrony measured using correlational models compared to the type of measurement and analysis of synchrony that we presented in the contributions in section one. In the meta-analysis, synchrony was measured using a computational method of analysis of synchrony using time-lag correlations; in the experimental section, we adopted a computational approach for creating the task, and we measured interpersonal synchrony in terms of "asynchrony" following previous literature (i.e., Fairhurst et al., 2013; Pecenka & Keller, 2011). In this sense, the final considerations might concern two conceptualizations of the same concept but using different approaches to measure synchrony. Overall, we provide the potential of new techniques for measuring synchrony within the therapy as a standpoint for clinical research and interventions, opening new clinical directions.

Future Directions

- Empirical-driven studies

According to the evolutionary-based approach, behavior is one of the first and direct available channels since birth. The sets of specific behaviors with varying goals and rhythms grow into the interactive dance within parent-child interaction, developing an 'internal' organization within a bio-behavioral synchronous system (Feldman, 2006; Feldman & Eidelman, 2009). In this sense, through synchronous behavioral and nonverbal exchanges, the parent's physiological systems and mental internalizations can impact the infant's biological organization and emerging consciousness.

However, maternal sensitivity and attunement mirroring are the building blocks for a secure organizational attachment system (Feldman, 2012; Isabella & Belsky, 1991; van IJzendoorn, 1995). Consistent with that, future studies could take a 'step forward' by adopting a more ecological approach to ascertain how cognitive and affective aspects can promote an organized system already within the primary relationship. For instance, the analysis of maternal sensitivity concerning the ability to synchronize might be an index of the quality of relations and of "being synchronous" with the mental and affective states of the other. In this sense, interpersonal synchrony could be an additional aspect that, along with the ability to be responsive, could underpin the ability to modulate behavior and emotions, shaping adaptive psychic and psychological structures. Therefore, the ability to anticipate and adapt to the other, along with the affective dispositions, might be one of the indexes of human bonding and relatedness within a broader evolutionary system. A possible application of this perspective would be through the 'still-face' paradigm (Tronick et al., 1978). Specifically, in light of our findings, we could suppose that a mother with high interpersonal asynchrony, regardless of how the partner adapts and responds, might be associated with pathological individual differences and a reduced representational and affective state of "like me." In turn, the child would respond with higher emotional dysregulation (i.e., Brazelton, 1974; Field, 1994) during the "unresponsive phase" as a result of reduced emotional mutual regulation. In this way, such an approach should promote the speculative hierarchical power of interpersonal synchrony in relation to maternal sensitivity and attachment relationships, extending seminal studies and multidisciplinary research fields.

- <u>Research in psychotherapy</u>

In relation to therapy, our findings might attempt to understand better the mechanisms underpinning the serious difficulties in "reaching" BPD patients during therapy (Caligor et al., 2018; Fonagy et al., 2015). Consistent with that, one of the main issues concerning individuals with BPD is the serious difficulties in creating the alliance (i.e., Wnuk et al., 2013) since the early stages of therapy (drop-out is around 30/35%; Stone, 2006).

Considering our results, we suggest that a future direction would be to implement training for the therapist to be more informed about the role of synchrony in psychotherapy and the new techniques that might be used to micro-analytically analyze how the interaction proceeded in terms of "being with." Moreover, another future direction should be the attempt to propose training sessions for both therapist and patient using video feedback to sensitize both the patient and therapist on the degree of synchrony and share the perspective of the two. That might be challenging among psychodynamic interventions (i.e., mentalization or transference-focused therapy), but that might be a way for "sharing" knowledge toward adaptive social learning and working on the "we mode" increasing epistemic trust (Fonagy et al., 2015; Fonagy & Campbell, 2017). Along with this vein, increasing awareness about the individual and shared perceptive states should enhance a dyadic approach that might help the transfert-controstransfert; in turn, support the reorganization of the patients' representation of self and self in relation to others. Inevitably, that might be challenging and quite complex to realize in practice in BPD at the interface with the serious interpersonal difficulties and acting out of BPD patients. However, as Fonagy and colleagues stated, BPD is "slow-changing" and needs time to deconstruct the "imaginary" world of these patients synchronizing with a disturbed intra-cultural communication created by a reduced epistemic trust (Fonagy et al., 2015).

Along this vein, the role of synchrony should be considered when ruptures occur. The adaptive potential role of synchrony should prevent ruptures from coming up by taking *high-but-imperfect* synchrony that would increase the emotional regulation with a therapist affectively available and sensitive (Muran & Eubanks, 2020). Such interpersonal dynamics might resemble a responsive state facilitating the *exploration* within a secure and safe interactive space. However, more studies are encouraged in this direction.

In sum, although "there is much left to be done," this thesis points out that cognitive and affective dispositions are potentially involved when "staying in sync" and that synchrony is also relevant within therapy in promoting the principles toward a working and trustworthy therapeutic setting. However, individual differences, as the developmental outcome of mental representations and affective expectancies, might affect behavioral and affective modulation within the dyadic interaction even when the partner is responsive. Furthermore, these processes rely upon the organization of the evolutionary behavioral and affective system but also on the quality of "walking in the shoes of another" or, even better, "walking *with"* (Jeannerod, 2006). Nevertheless, the therapy as a secure space would 'contain' the pathological evolution of cognitive-affective dimensions *through* a mutual synchronous behavior. That would drive the reorganization of the affective experience with the shared purpose of building 'together' different perspectives and consciousness of the mental representation of self and self *in relation to* the other.

"….fireflies flash in silent, hypnotic unison.
All of these astonishing feats of synchrony occur spontaneously-
as if the universe had an overwhelming desire for order".
(Steven H. Strogatz, 2003)

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